jc685 U.S. PTO 10/30/00

PTO/SB/05 (12/97)
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UTILITY PATENT APPLICATION TRANSMITTAL

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Attorney Docket No. 2000-1507A | *Total Pages*

First Named Inventor or Application Identifier

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Express Mail Label No.:

09/698020 U.S. PTO 10/30/00 Jc925

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents
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1. [X] Fee Transmittal Form
(Submit an original, and a duplicate for fee processing)

2. [X] Specification *[Total Pages - 101]*
(preferred arrangement set forth below)
- Descriptive title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the Invention
- Brief Summary of the Invention
- Brief Description of the Drawings *(if filed)*
- Detailed Description
- Claim(s)
- Abstract of the Disclosure

3. [X] Drawing(s) *(35 USC 113)* *[Total sheets - 20]*
4. [X] Oath or Declaration *[Total Pages - 3]*
a.1. [] Newly executed (original or copy)
a.2. [X] Unexecuted
b. [] Copy from a prior application (37 CFR 1.63(d))
(for continuation/divisional with Box 17 completed)
[Note Box 5 below]
i. [] DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).

5. [] Incorporation By Reference
(usable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. Microfiche Computer Program *(Appendix)*

7. []Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)
a. [] Computer Readable Copy
b. [] Paper Copy (identical to computer copy)
c. [] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. [] Assignment Papers (cover sheet & document(s))
9. [] 37 CFR 3.73(b) Statement [] Power of Attorney
(when there is an assignee)
10. [] English Translation Document *(if applicable)*
11. [] Information Disclosure Statement (IDS)/PTO-1449
[] Copies of IDS Citations
12. [] Preliminary Amendment
13. [X] Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)
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16. [] Other

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October 30, 2000

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of	:	THE COMMISSIONER IS AUTHORIZED TO CHARGE ANY DEFICIENCY IN THE FEE FOR THIS PAPER TO DEPOSIT ACCOUNT NO. 23-0975.
Naoya TOKUNAGA et al.	:	
Serial No. NEW	:	**Attn: APPLICATION BRANCH**
Filed October 30, 2000	:	**Attorney Docket No. 2000-1507A**
WAVEFORM EQUALIZATION CONTROLLER AND WAVEFORM EQUALIZATION CONTROL METHOD	:	

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New application $1,922.00

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The Commissioner is authorized to charge any deficiency or to credit any overpayment associated with this communication to Deposit Account No. 23-0975, with the EXCEPTION of deficiencies in fees for multiple dependent claims in new applications.

Respectfully submitted,

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09576200 - 103000

WAVEFORM EQUALIZATION CONTROLLER AND WAVEFORM EQUALIZATION CONTROL METHOD

FIELD OF THE INVENTION

The present invention relates to a waveform equalization controller and, more particularly, to a waveform equalization controller for controlling update of tap coefficients of a waveform equalizer which reduces transmission line distortion of a digital signal to be used in digital broadcasting.

BACKGROUND OF THE INVENTION

At the beginning, satellite broadcasting has mainly been performed as the digital broadcasting. However, in recent years, there is a growing tendency of digitization also in the terrestrial broadcasting. In the terrestrial broadcasting, the waveform equalization technique for reducing the transmission line distortion is essential. Hereinafter, a prior art waveform equalization controller in the ground wave digital broadcasting will be described taking a DTV (Digital Television) system using an 8-value VSB (Vestigial Side Band) modulation technique adopted in the U.S. as an example.

Figure 19 is a block diagram illustrating a structure of the waveform equalization controller in the DTV system.

In figure 19, the prior art waveform equalization controller comprises a waveform equalizer 101 for receiving

an input signal 100S and outputting an output signal 101S which is obtained by subjecting the input signal 100S to waveform equalization, an error estimation unit 1091 for estimating the error of the output signal 101S and outputting an error signal 1901S, and a coefficient updating amount calculation unit 103 for calculating a tap coefficient updating amount 106S on the basis of a step size 104S, a data 105S to be used for the coefficient update and the error signal 1901S. The error estimation unit 1901 comprises an output error estimation unit 1502 for receiving the output signal 101S and outputting an output error signal 1501S, and a coefficient updating error generation unit 1902.

Figure 20 is a diagram illustrating a structure of a signal format according to the DTV system. As shown in figure 20, the signal format according to the DTV system is composed of areas including a data signal 3101 such as video and audio, areas including a field synchronous signal 3102, and an area including a segment synchronous signal 3103.

Figure 21 is a diagram illustrating a structure of the field synchronous signal. As shown in figure 21, the field synchronous signal 3102 includes a PN511 signal 3201, three PN63 signals 3202, and a control signal 3203. The difference between the field synchronous signal #2 and the

field synchronous signal #1 is only that the second value in the PN63 signal 3202 is reversed. In figure 21, values on the left side (+7, +5, +3, +1, -4, -3, -5, -7) show 8 kinds of values which are taken on in the 8-value VSB modulation technique. One field of this DTV signal is composed of 832 symbols and 313 segments. The PN511 signal 3201 is obtained by a generating polynomial: PN511=X^9+X^7+X^6+X^4+X^3+X+1 (in this polynomial, "^" shows the power) and represented by Pre-load 010000000 (binary representation of the initial value). The PN63 signal 3202 is obtained by PN63=X^6+X+1 and represented by Pre-load 100111. The PN511 signal 3201 is composed of 511 symbols. The PN63 signals 3202 are composed of 63 symbols, respectively. The control signal 3203 is composed of 128 symbols. The whole of the field synchronous signal 3102 is composed of 828 symbols.

Next, the operation of the prior art waveform equalization controller is described with reference to the figures. In the waveform equalization controller according to the DTV system, as shown in figure 19, the waveform equalizer 101 performs the waveform equalization to the DTV signal which has been subjected to the 8-value modulation to reduce the distortion, and generates the output signal 101S. Then, the output error estimation unit 1502 generates the error between the output signal 101S and

the most likely one of the 8 kinds of symbol values as the output error signal 1501S. Figures 22(a) and 22(b) show the relationship between the output error signal and the error signal. The output error signal 1501S shown in figure 22(a) is converted by the coefficient updating error generation unit 1902 into the error signal 1901S as shown in figure 22(b) according to the value of the output signal 101S on the basis of Stop&Go algorithm described in "Blind Equalization and Carrier Recovery Using a "Stop-and-Go", in Decision-Directed Algorithm IEEE TRANSACTIONS ON COMMUNICATIONS, VOL.COM35, NO.9, SEPTEMBER 1987, pp.877-887". The coefficients updating amount calculation unit 103 generates the tap coefficient updating amount 106S on the basis of LMS (Least Mean Square) algorithm using the error signal 1901S, the step size 104S and the coefficient updating data 105S.

The LMS algorithm is the algorithm of performing the n-th update of tap coefficient Ci of tap i in a transversal filter in the waveform equalizer 101 on the basis of the following Expression 1.

$$Ci(n+1) = Ci(n) - \alpha \times e(n) \times di(n) \quad \text{...(Expression 1)}$$

Here, α denotes the step size 104S, e(n) denotes the error signal 1901S, di(n) denotes the coefficient updating data 105S, and $-\alpha \times e(n) \times di(n)$ denotes the tap coefficient updating amount 106S. Here, the coefficient updating data

105S is a data in tap i at the n-th updating.

There are two methods for generating the output error signal 1501S in the output error estimation unit 1502. One of the methods is capturing the PN511 signal 3201 and the PN63 signal 3203 included in the field synchronous signal 3102 in the DTV signal, comparing the signals with ideal values of the PN511 signal 3201 and the PN63 signal 3202, and outputting the error thereof as the output error signal 1501S.

The other method is comparing a data signal 3101 which is inserted in the data period of the DTV signal with the nearest fixed value of the 8-value VSB modulation, and outputting the error thereof as the output error signal 1501S.

Since the 8-value VSB modulation technique is used, the DTV signal has 8 kinds of values (+7, +5, +3, +1, -1, -3, -5, -7) as shown in figure 21. However, when the DTV signal which has been subjected to the 8-value VSB modulation is received, the signal is generally quantized in about 10 bits. For example in the case where the DTV signal which has been quantized in 10 bits does not have any distortion, only 8 kinds of fixed values can be taken on for the values represented by 10 bits (0 to 1023). The output error estimation unit 1502 calculates the error for the field synchronous signal 3102 of the input DTV signal

from the ideal values of the PN511 signal 3201 and PN63 signal 3202 and calculates the error for the data signal 3101 from the nearest value among the 8 kinds of fixed values, and outputs the error as the output error signal 1501S.

The prior art waveform equalization controller is constructed as described above and when this waveform equalization controller is used, it is possible that the waveform equalizer can be controlled and the DTV signal whose distortion is reduced can be obtained.

To be specific, the transmission line distortion of the input signal is estimated, and the learning control is performed so as to update the tap coefficient of the transversal filter included in the waveform equalizer in steps of a step size each time so that the distortion is cancelled out. Thereby, the signal whose transmission line distortion is reduced can be obtained as the output signal of the waveform equalizer.

However, the prior art waveform equalization controller has following problems.

The first problem is that the step size as the update step of the tap coefficient is fixed. Generally, when the step size is increased, the follow-up property in the case where the distortion is varied or the convergence speed at the initial operation is increased. On the other hand, the waveform equalization controller is easily affected by

noises, whereby the stability at the time of low C/N is decreased. Conversely, when the step size is reduced, the controller is hard to be affected by the noises and the stability at the low C/N time is increased. However, when the distortion is varied, the follow-up property to the variation or the convergence speed of the waveform equalization operation at the initial operation is reduced.

The second problem is that two multipliers are required in the coefficient updating amount calculation unit to calculate the coefficient updating amount of one tap, whereby the circuit scale becomes larger.

The third problem is that when it is judged as "Stop" in the Stop&Go algorithm the coefficient updating amount calculation unit outputs "0" up to the next iteration (update of the tap coefficient). Thus, the coefficient updating amount calculation unit is not utilized effectively as well as the follow-up property in the case where the distortion is varied or the convergence speed at the initial operation is reduced.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a waveform equalization controller which has both of the good follow-up property in the case where the distortion of the signal is varied or the higher convergence speed at the initial operation and the good stability at the low C/N time,

and realizes a high performance and a low cost.

Other objects and advantages of the present invention will become apparent from the detailed description and specific embodiments described are provided only for illustration since various additions and modifications within the spirit and scope of the invention will be apparent to those of skill in the art from the detailed description.

A waveform equalization controller according to a 1st aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal; a step size decision unit for receiving the error signal and a step size upper limit value and a step size lower limit value being an upper limit value and a lower limit value of a step size as a step for the update of the tap coefficient, adaptively generating a step size which corresponds to the error signal in a range of the step size upper limit value or smaller and the step size lower limit value or larger, and outputting the generated step size; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis

of the error signal, the step size and a data to be used for the tap coefficient update. Therefore, the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation, is hardly affected by noises, and has a higher stability at a low C/N time can be realized.

According to a 2nd aspect of the present invention, in the waveform equalization controller of the 1st aspect, the step size decision unit comprises: a multiplier for squaring the error signal to generate a square error; a square error storage unit for containing the square error which has been generated at a previous tap coefficient update; a subtracter for generating a difference between square errors, which is a difference between the square error output by the multiplier and the square error stored in the square error storage unit generated at the previous tap coefficient update; a first comparator for comparing the square error with a first threshold; a second comparator for comparing the square error with a second threshold; a third comparator for comparing an absolute value of the difference between square errors with a third threshold; a step size storage unit for containing a step size which has been used at the previous tap coefficient update; and a step size increasing/decreasing unit for receiving the step size

which has been stored in the step size storage unit, an output of the first comparator, an output of the second comparator, an output of the third comparator, the step size upper limit value and the step size lower limit value, and generating a step size which is to be used for this tap coefficient update. Therefore, the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation, is hardly affected by noises, and has a higher stability at a low C/N time can be realized.

According to a 3rd aspect of the present invention, in the waveform equalization controller of the 2nd aspect, the second threshold is such a value that when the square error is larger than the value the waveform equalizer is trending toward divergence; the first threshold is such a value that when the square error is smaller than the value the waveform equalizer is either converging or has converged; the third threshold is such a value that in the case where the square error is smaller than the first threshold, when an absolute value of the difference between square errors is larger than the third threshold the waveform equalizer is converging and when the absolute value is equal to or smaller than the third threshold the waveform equalizer has converged; and the step size increasing/decreasing unit decreases the step

size by a predetermined amount when it is judged from comparison results of the first to third comparators that the square error is larger than the second threshold, decreases the step size by a predetermined amount when the square error is smaller than the first threshold and the absolute value of the difference between square errors is equal to or smaller than the third threshold, increases the step size by a predetermined amount when the square error is smaller than the first threshold and the absolute value of the difference between square errors is larger than the third threshold, and does not change the step size in other cases. Therefore, the suitable step size is obtained according to the state of the waveform equalizer. Thereby, the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation, is hardly affected by noises, and has a higher stability at a low C/N time can be realized.

According to a 4th aspect of the present invention, in the waveform equalization controller of the 2nd aspect, the second threshold is such a value that when the square error is larger than the value the waveform equalizer is trending toward divergence; the first threshold is such a value that when the square error is smaller than the value the waveform equalizer is either converging or has converged; the third

threshold is such a value that in the case where the square error is smaller than the first threshold, when an absolute value of the difference between square errors is larger than the third threshold the waveform equalizer is converging and when the absolute value is equal to or smaller than the third threshold the waveform equalizer has converged; and the step size increasing/decreasing unit decreases the step size at a predetermined rate when it is judged from comparison results of the first to third comparators that the square error is larger than the second threshold, decreases the step size at a predetermined rate when the square error is smaller than the first threshold and the absolute value of the difference between square errors is equal to or smaller than the third threshold, increases the step size at a predetermined rate when the square error is smaller than the first threshold and the absolute value of the difference between square errors is larger than the third threshold, and does not change the step size in other cases. Therefore, the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation, is hardly affected by noises, and has a higher stability at a low C/N time can be realized.

A waveform equalization controller according to a 5th

aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal; a signal judgement unit for judging whether a probability of a judgement error in the error estimation for the output signal is larger or smaller, and outputting a judgement signal; a step size decision unit for receiving the judgement signal and outputting a value according to the judgement signal as a step size which is a step for the update of the tap coefficient; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, the step size, and a data to be used for the tap coefficient update. Therefore, the step size can be increased according to the probability of the judgement error for the output signal, whereby the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

According to a 6th aspect of the present invention, in the waveform equalization controller of the 5th aspect, the

signal judgement unit outputs three kinds of the judgement signal of: the judgement signal indicating that the output signal is known; the judgement signal indicating that the probability of the judgement error for the output signal is smaller; and the judgement signal indicating that the probability of the judgement error for the output signal is larger. Therefore, the step size can be increased or decreased according the probability of the judgement error for the output signal, whereby the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

According to a 7th aspect of the present invention, in the waveform equalization controller of the 6th aspect, the step size decision unit outputs a first step size set value as the step size when the judgement signal indicates that the output signal is known, outputs a second step size set value which is smaller than the first step size set value when the judgement signal indicates that the probability of the judgement error for the output signal is smaller, and outputs a third step size set value which is smaller than the second step size set value when the judgement signal indicates that the probability of the judgement error for the output signal is larger. Therefore, the step size can

be increased or decreased according to the probability of the judgement error for the output signal, whereby the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

A waveform equalization controller according to an 8th aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of the output signal of the waveform equalizer from the output signal, and outputting an error signal; a step size decision unit for receiving the error signal, a threshold and plural step size set values, and deciding a step size as a step for the update of the tap coefficient; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, the step size and a data to be used for the tap coefficient update. Therefore, one of the step sizes can be selected according to the relationship between the error signal and the threshold, whereby the waveform equalization controller which has a follow-up property in the case where the transmission line distortion

of the input signal is varied and a higher convergence speed at the initial operation can be realized.

According to a 9th aspect of the present invention, in the waveform equalization controller of the 8th aspect, the plural step size set values are a first step size set value and a second step size set value which is larger than the first step size set value, and the step size decision unit comprises: a comparator for comparing an absolute value of the error signal with the threshold; and a selector for selecting one of the first step size set value and the second step size set value on the basis of a comparison result output by the comparator, and outputting the selected step size as the step size. Therefore, one of the step sizes can be selected on the basis of the result of the comparison between the error signal and the threshold, whereby the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

According to a 10th aspect of the present invention, in the waveform equalization controller of the 9th aspect, the threshold value is such a value that when the absolute value of the error signal is equal to or smaller than the threshold the waveform equalizer has nearly converged; and the step size decision unit outputs the first step size set

value as the step size when the absolute value of the error signal is equal to or smaller than the threshold, and outputs the second step size set value as the step size when the absolute value of the error signal exceeds the threshold. Therefore, on the basis of the result of the comparison between the error signal and the threshold by the comparator, the larger step size can be selected when it is judged that the waveform equalizer has not converged yet. Thus, the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

A waveform equalization controller according to a 11th aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal; an error quantization unit for converting the error signal into a quantized error signal having a value of powers of 2, and outputting the quantized error signal; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis

of the quantized error signal, the step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update. Therefore, the two-time multiplication which is required in the prior art can be replaced with one multiplication and one shift operation. Thus, the waveform equalization controller which attains the same performance as the prior art as well as has a small circuit scale can be realized.

According to a 12th aspect of the present invention, in the waveform equalization controller of the 11th aspect, the error quantization unit converts the error signal into the quantized error signal having the same sign as the error signal and a maximum absolute value which is equal to or smaller than an absolute value of the error signal among the powers of 2, and outputting the quantized error signal. Therefore, the two-time multiplication is required to obtain the tap coefficient updating amount in the prior art while it can be replaced with one multiplication and one shift operation. Thus, the waveform equalization controller which attains the same performance as the prior art as well as has a small circuit scale can be realized.

According to a 13th aspect of the present invention, in the waveform equalization controller of the 11the aspect, the error quantization unit converts the error signal into the quantized error signal having the same sign as the error

signal and a minimum absolute value which is equal to or larger than an absolute value of the error signal among the powers of 2, and outputting the quantized error signal. Therefore, the two-time multiplication is required to obtain the tap coefficient updating amount in the prior art while it can be replaced with one multiplication and one shift operation. Thus, the waveform equalization controller which attains the same performance as the prior art as well as has a small circuit scale can be realized.

A waveform equalization controller according to a 14th aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal; a data quantization unit for converting a data to be used for the tap coefficient update into a quantized data having a value of powers of 2, and outputting the quantized data; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and the quantized data. Therefore, the two-time multiplication which is required

in the prior art can be replaced with one multiplication and one shift operation, whereby the waveform equalization controller which attains the same performance as the prior art and has a small circuit scale can be realized.

According to a 15th aspect of the present invention, in the waveform equalization controller of the 14th aspect, the data quantization unit converts the data to be used for the tap coefficient update into a quantized data having the same sign as the data to be used for the tap coefficient update and a maximum absolute value which is equal to or smaller than an absolute value of the data to be used for the tap coefficient update among the powers of 2, and outputting the quantized date. Therefore, the two-time multiplication is required to obtain the tap coefficient updating amount in the prior art while it can be replaced with one multiplication and one shift operation. Thus, the waveform equalization controller which attains the same performance as the prior art and has a small circuit scale can be realized.

According to a 16th aspect of the present invention, in the waveform equalization controller of the 14th aspect, the data quantization unit converts the data to be used for the tap coefficient update into a quantized data having the same sign as the data to be used for the tap coefficient update and a minimum absolute value which is equal to or

larger than an absolute value of the data to be used for the tap coefficient update among the powers of 2, and outputting the quantized data. Therefore, the two-time multiplication is required to obtain the tap coefficient updating amount in the prior art while it can be replaced with one multiplication and one shift operation. Thus, the waveform equalization controller which attains the same performance as the prior art and has a small circuit scale can be realized.

A waveform equalization controller according to a 17th aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal; a step size quantization unit for converting a step size as a step for the update of the tap coefficient into a quantized step size having a value of powers of 2, and outputting the quantized step size; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, the quantized step size and a data to be used for the tap coefficient update. Therefore, the two-time

multiplication which is required in the prior art can be replaced with one multiplication and one shift operation. Thus, the waveform equalization controller which attains the same performance as the prior art as well as has a small circuit scale can be realized.

According to an 18th aspect of the present invention, in the waveform equalization controller of the 17th aspect, the step size quantization unit converts the step size into the quantized step size having a maximum value which is equal to or smaller than the step size among the powers of 2, and outputs the quantized step size. Therefore, the two-time multiplication is required to obtain the tap coefficient updating amount in the prior art while it can be replaced with one multiplication and one shift operation. Thus, the waveform equalization controller which attains the same performance as the prior art and has a small circuit scale can be realized.

According to a 19th aspect of the present invention, in the waveform equalization controller of the 17th aspect, the step size quantization unit converts the step size into the quantized step size having a minimum value which is equal to or larger than the step size among the powers of 2, and outputting the quantized step size. Therefore, the two-time multiplication is required to obtain the tap coefficient updating amount in the prior art while it can

be replaced with one multiplication and one shift operation. Thus, the waveform equalization controller which attains the same performance as the prior art and has a small circuit scale can be realized.

A waveform equalization controller according to a 20th aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal which is obtained by making the estimated error 0 when the estimated error is an error corresponding to a predetermined range of the output signal; a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update; and a coefficient update timing control unit for receiving the error signal and outputting a update timing signal which controls a timing when the coefficient updating amount calculation unit calculates the tap coefficient updating amount at intervals of plural symbols. Therefore, the tap coefficient updating amount is calculated by the

coefficient updating amount calculation unit when the error signal is not "0", whereby the coefficient updating interval can be reduced with relative to the waveform equalization controller which performs the coefficient update at a predetermined symbol intervals. Thus, the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

According to a 21st aspect of the present invention, in the waveform equalization controller of the 20th aspect, the coefficient update timing control unit controls the timing of the coefficient updating amount calculation unit calculating the tap coefficient updating amount to be at a first symbol after an interval of predetermined symbols or more from a previous timing and when the error signal is not 0. Therefore, the coefficient updating interval can be reduced with relative to the waveform equalization controller which performs the coefficient update at previously determined symbol intervals. Thus, the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

A waveform equalization controller according to a 22nd

aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit comprising an output error estimation unit for receiving an output signal of the waveform equalizer and outputting an output error signal, and a coefficient updating error generation unit for receiving the output error signal and the output signal and outputting an error signal which is obtained by reducing a partial section of the output error signal at a predetermined rate; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a date to be used for the tap coefficient update. Therefore, the output error signal which has been converted into "0" by the coefficient updating error generation unit is converted into an error signal which is obtained by multiplying the output error signal by a predetermined rate to decrease the value. Thus, the error signal which can be used for the tap coefficient update is increased in number as compared to Stop&Go algorithm. Therefore, the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input

signal is varied and a higher convergence speed at the initial operation can be realized.

A waveform equalization controller according to a 23rd aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error rate measuring circuit for receiving an output signal of the waveform equalizer and generating an error rate signal which indicates a rate of an error included in the output signal; an error estimation unit comprising an output error estimation unit for receiving the output signal of the waveform equalizer and outputting an output error signal, and a coefficient updating error generation unit for receiving the output error signal, the output signal and the error rate signal and outputting an error signal; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update. Therefore, the update interval of the tap coefficient is reduced and further the error signal which can be used for the tap coefficient update is increased in number. Thus, the waveform equalization controller

which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

According to a 24th aspect of the present invention, in the waveform equalization controller of the 23rd aspect, the coefficient updating error generation unit outputs the same value as the output error signal, as the error signal, when it is detected from the error rate signal that the rate of the error included in the output signal is smaller than a predetermined rate. Therefore, the update interval of the tap coefficient is reduced and further the error signal which can be used for the tap coefficient update is increased in number. Thus, the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

A waveform equalization control method according to a 25th aspect of the present invention for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprises: an error estimation step of estimating an error of an output signal of the waveform equalizer from the output signal,

and generating an error signal; a step size decision step of adaptively deciding a step size in a range of a step size upper limit value as an upper limit value of a step size which is a step for the update of the tap coefficient or smaller, and a step size lower limit value as a lower limit value of the step size or larger, on the basis of the error signal; and a coefficient updating amount calculation step of calculating a tap coefficient updating amount on the basis of the error signal, the step size and a data to be used for the tap coefficient update. Therefore, the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation, is hardly affected by noises, and has a higher stability at a low C/N time can be realized.

According to a 26th aspect of the present invention, in the waveform equalization control method of the 25th aspect, the step size decision step comprises: a multiplication step of squaring the error signal to generate a square error; a subtraction step of generating a difference between square errors, which is a difference between the square error generated at a previous tap coefficient update and the square error generated in the multiplication step; a first comparison step of comparing the square error with a first threshold; a second comparison

step of comparing the square error with a second threshold; a third comparison step of comparing an absolute value of the difference between square errors with a third threshold; and a step size generation step of generating a step size which is to be used for this tap coefficient update on the basis of the step size which has been used at the previous tap coefficient update, a comparison result in the first comparison step, a comparison result in the second comparison step, a comparison result in the third comparison step, the step size upper limit value and the step size lower limit value. Therefore, the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation, is hardly affected by noises, and has a higher stability at a low C/N time can be realized.

A waveform equalization control method according to a 27th aspect for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprises: a step of estimating an error of an output signal of the waveform equalizer from the output signal, and generating an error signal; a step of judging whether a probability of a judgement error in the error estimation for the output signal is larger or smaller, and

generating a judgement signal; a step of deciding a step size which is a step for the update of the tap coefficient on the basis of the judgement signal; and a step of calculating a tap coefficient updating amount on the basis of the error signal, the step size, and a data to be used for the tap coefficient update. Therefore, the step size can be increased according the probability of the judgement error for the output signal, whereby the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

A waveform equalization control method according to a 28th aspect of the present invention for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprises: an error estimation step of estimating an error of the output signal of the waveform equalizer from the output signal, and generating an error signal; a step size decision step of deciding a step size as a step for the update of the tap coefficient on the basis of the error signal, a threshold and plural step size set values; and a coefficient updating amount calculation step of calculating a tap coefficient updating amount on the basis of the error signal, the step

size and a data to be used for the tap coefficient update. Therefore, one of the step sizes can be selected according to the relationship between the error signal and the threshold, whereby the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

According to a 29th aspect of the present invention, in the waveform equalization control method according to the 28th aspect, the plural step size set values are a first step size set value and a second step size set value which is larger than the first step size set value, and the step size decision step comprises: a comparison step of comparing an absolute value of the error signal with the threshold; and a selection step of selecting one of the first step size set value and the second step size set value as the step size on the basis of a comparison result in the comparison step. Therefore, one of the step sizes can be selected on the basis of the result of the comparison between the error signal and the threshold, whereby the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

A waveform equalization control method according to a 30th aspect of the present invention for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprises: an error estimation step of estimating an error of an output signal of the waveform equalizer from the output signal, and generating an error signal which is obtained by making the estimated error 0 when the estimated error is an error corresponding to a predetermined range of the output signal; a coefficient update timing control step of generating an update timing signal which controls a timing of calculating the tap coefficient updating amount at intervals of plural symbols on the basis of the error signal; and a coefficient updating amount calculation step of calculating a tap coefficient updating amount at the timing controlled by the update timing signal on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update. Therefore, the tap coefficient updating amount is calculated in the coefficient updating amount calculation step when the error signal is not "0", whereby the coefficient updating interval can be reduced with relative to the waveform equalization control method for performing the coefficient update at a predetermined symbol intervals.

Thus, the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

According to a 31st aspect of the present invention, in the waveform equalization control method of the 30th aspect, the update timing signal is generated for controlling the timing of calculating the tap coefficient updating amount in the coefficient update timing control step to be at a first symbol after an interval of predetermined symbols or more from a previous timing and when the error signal is not 0. Therefore, the coefficient updating interval can be reduced with relative to the waveform equalization control method for performing the coefficient update at previously determined symbol intervals. Thus, the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

A waveform equalization control method according to a 32nd aspect for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprises: a step of estimating an output

error from an output signal of the waveform equalizer and generating an output error signal; a step of generating an error signal which is obtained by reducing a partial section of the output error signal at a predetermined rate on the basis of the output error signal and the output signal; and a step of calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a date to be used for the tap coefficient update. Therefore, the output error signal which has been converted into "0" in the step of generating the coefficient updating error signal is converted into an error signal which is obtained by multiplying the output error signal by a predetermined rate to decrease the value. Thus, the error signal which can be used for the tap coefficient update is increased in number as compared to Stop&Go algorithm. Therefore, the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

A waveform equalization control method according to a 33rd aspect for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprises: an output error estimation step

of estimating an output error from an output signal of the waveform equalizer, and generating an output error signal; an error rate signal generation step of generating an error rate signal which indicates a rate of an error included in the output signal of the waveform equalizer; a coefficient updating error generation step of generating an error signal to be used for the update of the tap coefficient on the basis of the output error signal, the output signal and the error rate signal; and a coefficient updating amount calculation step of calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update. Therefore, the update interval of the tap coefficient is reduced and further the error signal which can be used for the tap coefficient update is increased in number. Thus, the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

According to a 34th aspect of the present invention, in the waveform equalization control method according to the 33rd aspect, when it is detected from the error rate signal in the coefficient updating error generation step that the rate of the error included in the output signal

is smaller than a predetermined rate, the same value as the output error signal is generated as the error signal. Therefore, the update interval of the tap coefficient is reduced and further the error signal which can be used for the tap coefficient update is increased in number. Thus, the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram illustrating a structure of a waveform equalization controller according to a first embodiment of the present invention.

Figure 2 is a block diagram illustrating a structure of a step size decision unit according to the first embodiment.

Figure 3 is a diagram for explaining the operation of a step size increasing/decreasing unit according to the first embodiment.

Figure 4 is a block diagram illustrating a waveform equalization controller according to a second embodiment of the present invention.

Figure 5 is a diagram showing the relationship between a judgement signal and an output signal of the waveform equalization controller according to the second embodiment.

Figure 6 is a block diagram illustrating a structure of a waveform equalization controller according to a third embodiment of the present invention.

Figure 7 is a block diagram illustrating a structure of a waveform equalization controller according to a fourth embodiment of the present invention.

Figure 8 is a diagram showing the relationship between an error signal and a quantized error signal of the waveform equalization controller according to the fourth embodiment.

Figure 9 is a block diagram illustrating a structure of a waveform equalization controller according to a fifth embodiment of the present invention.

Figure 10 is a diagram showing the relationship between a data and a quantized data of the waveform equalization controller according to the fifth embodiment.

Figure 11 is a block diagram illustrating a structure of a waveform equalization controller according to a sixth embodiment of the present invention.

Figure 12 is a diagram showing the relationship between a step size and a quantized step size of the waveform equalization controller according to the sixth embodiment.

Figure 13 is a block diagram illustrating a structure of a waveform equalization controller according to a seventh embodiment of the present invention.

Figures 14(a)-14(d) are diagrams for explaining the

timing of tap coefficient update in the waveform equalization controller according to the seventh embodiment.

Figure 15 is a block diagram illustrating a structure of a waveform equalization controller according to an eighth embodiment of the present invention.

Figures 16(a)-16(b) are diagrams for explaining the operation of the waveform equalization controller according to the eighth embodiment of the present invention.

Figure 17 is a block diagram illustrating a structure of a waveform equalization controller according to a ninth embodiment of the present invention.

Figures 18(a)-18(d) are diagrams for explaining the operation of the waveform equalization controller according to the ninth embodiment of the present invention.

Figure 19 is a block diagram illustrating a structure of a prior art waveform equalization controller.

Figure 20 is a diagram illustrating a structure of a DTV signal format.

Figure 21 is a diagram illustrating a structure of a field synchronous signal format in the DTV signal.

Figures 22(a)-22(b) are diagrams for explaining the operation of the prior art waveform equalization controller.

Figure 23 is a flowchart showing the operation of the

waveform equalization controller according to the first embodiment.

Figure 24 is a flowchart showing the operation of the waveform equalization controller according to the first embodiment.

Figure 25 is a flowchart showing the operation of the waveform equalization controller according to the second embodiment.

Figure 26 is a flowchart showing the operation of the waveform equalization controller according to the third embodiment.

Figure 27 is a flowchart showing the operation of the waveform equalization controller according to the seventh embodiment.

Figure 28 is a flowchart showing the operation of the waveform equalization controller according to the eighth embodiment.

Figure 29 is a flowchart showing the operation of the waveform equalization controller according to the ninth embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, a waveform equalization controller and a waveform equalization control method according to embodiments of the present invention will be described with reference to the drawings.

[Embodiment 1]

A waveform equalization controller and a waveform equalization control method according to the first embodiment of the present invention will be described with reference to the figures.

Figure 1 is a block diagram illustrating a structure of the waveform equalization controller according to the first embodiment. In figure 1, the waveform equalization controller of the first embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 102 for estimating the error of the output signal 101S and outputting an error signal 102S, a coefficient updating amount calculation unit 103 for calculating a tap coefficient updating amount 106S on the basis of the error signal 102S, a step size 104S and a data 105S to be used for coefficient update, and a step size decision unit 104 for receiving the error signal 102S, a step size upper limit value 107S and a step size lower limit value 108S, and generating and outputting the step size 104S.

Figure 2 is a block diagram illustrating a structure of the step size decision unit 104 included in the waveform equalization controller of the first embodiment. In figure

2, the step size decision unit 104 comprises a multiplier 201 for squaring the error signal 102S and generating a square error 201S, a square error storage unit 202 for containing the square error 201S, a subtracter 203 for calculating the difference between the square error 201S output by the multiplier 201 and the square error stored in the square error storage unit 202 and outputting the difference 202S between the square errors, a first comparator 204 for comparing the square error 201S with a first threshold, a second comparator 205 for comparing the square error 201S with a second threshold, a third comparator 206 for comparing the absolute value of the difference 202S between the square errors with a third threshold, a step size storage unit 207 for containing the step size, and a step size increasing/decreasing unit 208.

Next, the operation of the waveform equalization controller according to the first embodiment is described with reference to the figures.

Figure 23 is a flowchart showing the operation of the waveform equalization controller according to the first embodiment.

Initially, a signal from the transmission line is input to the waveform equalizer 101 as the input signal 100S via a tuner and a wave detector (not shown). The error estimation unit 102 estimates an error to be used for the

tap coefficient update on the basis of the output signal 101S output by the waveform equalizer 101, generates the error signal 102S on the basis of the estimated error, and outputs the error signal 102S (step S101). Like the output error estimation unit 1502 of the prior art, when the output signal 101S takes on only one value the error estimation unit 102 estimates the difference between the output signal 101S and its ideal value as the error as the error, generates the error signal 102S corresponding to the size of the error, and outputs the error signal 102S. On the other hand, when the output signal 101S takes on multiple values the error estimation unit 102 estimates the difference between the output signal 101S and an ideal value which is nearest to the output signal 101S among their multiple ideal values as the error, generates the error signal 102S corresponding to the size of the error, and outputs the error signal 102S. In this first embodiment, the input signal 100S is not limited to the DTV signal.

The step size decision unit 104 receives the error signal 102S, the step size upper limit value 107S as a value for deciding the upper limit of the step size and the step size lower limit value 108S as a value for deciding the lower limit of the step size, decides the step size 104S, the value of which is varied according to the error signal 102S within a range of the step size lower limit value 108S or larger

and the step size upper limit value 107S or smaller, and outputs the step size 104S (step S102). The coefficient updating amount calculation unit 103 receives the error signal 102S, the step size 104S and the data 105S, performs the multiplication of these as shown in the second term on the right side in the above-mentioned (Expression 1), and outputs the tap coefficient updating amount 106S (step S103). Then, the tap coefficient updating amount 106S is used in the waveform equalizer 101 to update the tap coefficient shown by (Expression 1). Here, the processes of steps S101 to S103 and the update of the tap coefficient in the waveform equalizer 101 are repeated as long as the waveform equalization is performed in the waveform equalizer 101.

As the data 105S used for the coefficient update, data which are stored in a data FIFO (not shown) included in the waveform equalizer 101 are employed. The waveform equalization controller can separately comprise a FIFO for containing the coefficient updating data 105S. Further, as the upper limit value 107S of the step size and the lower limit value 108S of the step size, values which have previously been stored in a register (not shown) included in the waveform equalization controller are employed.

Next, the operation of the step size decision unit 104 is described.

Figure 24 is a flowchart showing the operation of the

step size decision unit 104 of the first embodiment.

The multiplier 201 squares the error signal 102S to generate the square error 201S (step S201). The square error storage unit 202 contains the square error at the previous coefficient updating. The subtracter 203 calculates the difference between the square error 201S and the square error at the previous coefficient updating, and outputs the difference 202S of the square errors (step S202). Then, the square error storage unit 202 contains the present square error 201S. The first comparator 204 compares the square error 201S with the first threshold (step S203). The second comparator 205 compares the square error 201S with the second threshold (step S204). The third comparator 206 compares the absolute value of the difference 202S of the square errors with the third threshold (step S205). The comparison result of the first comparator 204, the comparison result of the second comparator 205, the comparison result of the third comparator 206, the step size at the previous coefficient updating stored in the step size storage unit 207, the step size upper limit value 107S and the step size lower limit value 108S are input to the step size increasing/decreasing unit 208.

When the square error 201S is larger than the second threshold, the waveform equalization operation for reducing the transmission line distortion in the waveform equalizer

101 is in an uncontrollable state, i.e., trending toward divergence. On the other hand, when the square error 201S is smaller than the first threshold, the waveform equalization operation in the waveform equalizer 101 is either converging or has converged. When the square error 201S is smaller than the first threshold, and when the absolute value of the difference 202S between the square errors is larger than the third threshold, the waveform equalization operation in the waveform equalizer 101 is converging, and when the absolute value is equal to or smaller than the third threshold, the waveform equalization operation in the waveform equalizer 101 has converged.

Practically, rough values of the first to third thresholds are set by simulation, and then the first to third thresholds are finally set on the judgement of the designer made by considering the result of the actual operation, respectively.

To be specific, the second threshold is set to such a value that the designer judges when the square error 201S is larger than that value, the waveform equalization operation in the waveform equalizer 101 is trending toward divergence. The first threshold is set to such a value that the designer judges when the square error 201S is smaller than that value, the waveform equalization operation in the waveform equalizer 101 is either converging or has converged.

The third threshold is set to such a value that the designer judges when the square error 201S is smaller than the first threshold and when the absolute value of the difference 202S between the square errors is larger than the third threshold, the waveform equalization operation in the waveform equalizer 101 is converging, and when the absolute value of the difference is equal to or smaller than the third threshold, the waveform equalization operation in the waveform equalizer 101 has converged.

Then, the operation of the step size increasing/decreasing unit 208 is described with reference to the figures.

Figure 3 is a diagram for explaining the operation of the step size increasing/decreasing unit 208 in the waveform equalization controller according to the first embodiment.

In figure 3, when the square error 201S is within an area 1, i.e., when it is judged by the second comparator 205 that the square error 201S is larger than the second threshold, it is judged that the waveform equalizer 101 is trending to divergence. Therefore, the step size increasing/decreasing unit 208 obtains a new step size which is obtained by decreasing the previous step size stored in the step size storage unit 207 by a prescribed amount.

When the square error 201S is within an area 2, i.e., it is judged by the first comparator 204 and the second

comparator 205 that the square error 201S is the first threshold or larger and the second threshold or smaller, it is judged that the waveform equalizer 101 is operating stably. Therefore, the step size increasing/decreasing unit 208 takes the same step size as the previous step size stored in the step size storage unit 207 as a new step size.

When the square error 201S and the difference 202S between the square errors are within an area 3 or area 5, i.e., it is judged by the first comparator 204 that the square error 201S is smaller than the first threshold and it is judged by the third comparator 206 that the absolute value of the difference 202S between the square errors is larger than the third threshold value, the waveform equalizer 101 is judged to be converging. Therefore, the step size increasing/decreasing unit 208 obtains a new step size which is obtained by increasing the previous step size stored in the step size storage unit 207 by a prescribed amount to increase the convergence speed more. Here, the step size is increased in the area 5 to also suitably cope with dynamic ghost, i.e., ghost varying with time.

When the square error 201S and the difference 202S between the square errors are within an area 4, i.e., it is judged by the first comparator 204 and the third comparator 206 that the square error 201S is smaller than the first threshold and the absolute value of the difference

202S between the square errors is equal to or smaller than the third threshold, the waveform equalizer 101 is judged to have almost converged. Therefore, the step size increasing/decreasing unit 208 obtains a new step size which is obtained by decreasing the previous step size stored in the step size storage unit 207 by a prescribed amount to ensure the stability at the low C/N time.

Further, when the new step size is larger than the step size upper limit value 107S, the step size increasing/decreasing unit 208 outputs the step size upper limit value 107S as the step size 104S. When the new step size is smaller than the step size lower limit value 108S, the step size increasing/decreasing unit 208 outputs the step size lower limit value 108S as the step size 104S. In other cases, the new step size is output as the step size 104S (step S206).

As described above, according to the waveform equalization controller of the first embodiment, the step size decision unit 104 is provided which judges the status of the waveform equalizer 101 from the square error 201S and the difference 202S between the square errors, and obtains the suitable step size 104S by correspondingly increasing or decreasing the previous step size. Thus, the waveform equalization controller having a higher convergence speed and a higher stability at the low C/N time

can be realized.

In this first embodiment, the square error is used as the index for increasing or decreasing the step size. However, the index for increasing or decreasing the step size is not limited to the square error. The same function can be attained also with the n-th power of the error ("n" is 1 or an integer of 3 or more). In this case, when "n" is an odd number, the absolute value of the n-th power of the error is used for example in the first comparator 204 or second comparator 205 as the n-th power error.

Further, in this first embodiment, when the step size increasing/decreasing unit 208 increases/decreases the step size, a prescribed amount is added/subtracted to/from the previous step size. However, the way of increasing/decreasing the step size is not limited to this. The step size can be increased/decreased by increasing/decreasing the previous step size by a prescribed ratio. To be specific, when the step size is to be increased, the previous step size is multiplied by a prescribed value which is larger than 1, for example 1.1. When the step size is to be decreased, the previous step size is multiplied by a prescribed value which is smaller than 1, for example 0.9.

[Embodiment 2]

A waveform equalization controller according to the

second embodiment of the present invention will be described with reference to the figures.

Figure 4 is a block diagram illustrating a structure of the waveform equalization controller according to the second embodiment. In figure 4, the waveform equalization controller of the second embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 102 for estimating the error of the output signal 101S and outputting an error signal 102S, a coefficient updating amount calculation unit 103 for calculating a tap coefficient updating amount 106S on the basis of the error signal 102S, a step size 104S and a data 105S to be used for the coefficient update, a signal judgement unit 401 for outputting a judgement signal 401S, and a step size decision unit 402 for outputting the step size 104S in accordance with the judgement signal 401S.

Next, the operation of the waveform equalization controller according to the second embodiment is described with reference to the figures.

Figure 25 is a flowchart showing the operation of the waveform equalization controller according to the second embodiment.

The error estimation unit 102 estimates the error to

be used for the tap coefficient update from the output signal 101S, generates the error signal 102S on the basis of the estimated error, and outputs the error signal 102S (step S301). The signal judgement unit 401 judges the kind of the contents of the output signal 101S from the synchronous signal included in the input signal 100S, generates whether the probability of a judgement error in the error estimated by the error estimation unit 102 for the output signal 101S is higher or lower as the judgement signal 401S, and outputs the judgement signal 401S (step S302).

Hereinafter, the description is given taking a case where the input to the waveform equalizer 101 is a DTV signal as an example. Figure 5 shows the relationship between the judgement signal 401S and the output signal 101S. In figures 20 and 21, the symbol values of the segment synchronous signal 3103, and the PN511 signal 3201 and the PN63 signal 3202 in the field synchronous signal are previously known. Therefore, no judgement error occurs in the error estimated by the error estimation unit 102 for the output signal 101S. In this case, the error signal 102S always shows a correct value. Therefore, the signal judgement unit 401 outputs "0" as the judgement signal 401S. The control signal 3203 can take on only two values among eight values of the DTV signal. Therefore, the probability of the judgement error in the error estimated by the error

estimation unit 102 for the output signal 101S is low. In this case, the error signal 102S shows a nearly correct value. Therefore, the signal judgement unit 401 outputs "1" as the judgement signal 401S. Other signals can take on all of the eight values among eight values of the DTV signal. Thus, the probability of the judgement error in the error estimated by the error estimation unit 102 for the output signal 101S is high. Since the probability of the error signal 102S showing a correct value is low in this case, the signal judgement unit 401 outputs "2" as the judgement signal 401S.

The step size decision unit 402 selects one of three kinds of step sizes which have previously been set according to the values of the judgement signal 401S, and outputs the selected step size 104S. When the judgement signal 401S is "0", the largest step size is output as the step size 104S. When the judgement signal 401S is "1", the second largest step size is output as the step size 104S. When the judgement signal 401S is "2", the smallest step size is output as the step size 104S (step S303). The coefficient updating amount calculation unit 103 receives the error signal 102S, the step size 104S and the data 105S, performs the multiplication of these, and outputs the tap coefficient updating amount 106S (step S304). Then, the tap coefficient updating amount 106S is used in the waveform equalizer 101

to update the tap coefficient shown by (Expression 1). Here, the processes of steps S301 to S304 and the update of the tap coefficient in the waveform equalizer 101 are repeated as long as the waveform equalization is performed in the waveform equalizer 101.

As described above, according to the waveform equalization controller of the second embodiment, the signal judgement unit 401 for outputting the judgement signal 401S according to the probability of the judgement error in the error by the error estimation unit 102 in regard to the output signal 101S, and the step size decision unit 402 for outputting one of the step sizes which have previously been set according to the judgement signal 401S are provided. Therefore, the value of the step size 104S can be changed according to the probability of the judgement error in the error estimation for the output signal 101S. When the error signal 102S is correct, the tap coefficient updating amount 106S is increased. Therefore, the convergence speed can be increased, whereby the waveform equalization controller having a higher convergence speed and a higher stability at the low C/N time can be realized.

In this second embodiment, the description is given of a case where the input signal 100S is the DTV signal. However, the input is not limited to the DTV signal. In addition, while the judgement signal 401S is set to have

three levels, it is not limited to the three levels and can be set to have two levels, or four or more levels. Further, the signal value of the judgement signal 401S are not limited to "0", "1" and "2". Furthermore, the step size 104S to be selected is not limited to three kinds and can have two kinds, or four or more kinds.

Further, in this second embodiment, the description is given of a case where the signal judgement unit 401 generates the judgement signal 401S using the synchronous signal included in the input signal 100S. However, the signal judgement unit 401 can generate the judgement signal 401S using the synchronous signal included in the output signal 101S.

[Embodiment 3]

A waveform equalization controller according to the third embodiment of the present invention will be described with reference to the figures.

Figure 6 is a block diagram illustrating a structure of the waveform equalization controller according to the third embodiment. In figure 6, the waveform equalization controller of the third embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 102 for estimating the error of

the output signal 101S and outputting an error signal 102S, a coefficient updating amount calculation unit 103 for calculating a tap coefficient updating amount 106S on the basis of the error signal 102S, a step size 104S and a data 105S to be used for the coefficient update, and a step size decision unit 601 for receiving the error signal 102S, a threshold 601S, a first step size set value 602S and a second step size set value 603S, and generating and outputting the step size 104S. The step size decision unit 601 comprises a comparator 602 and a selector 603.

Next, the operation of the waveform equalization controller according to the third embodiment is described with reference to the figures.

Figure 26 is a flowchart showing the operation of the waveform equalization controller according to the third embodiment.

The error estimation unit 102 estimates the error on the basis of the output signal 101S output by the waveform equalizer 101 to be used for the tap coefficient update, and outputs the estimated error as the error signal 102S (step S401). The comparator 602 compares the absolute value of the error signal 102S with the threshold 601S (step S402). From the comparison result of the comparator 602, when the absolute value of the error signal 102S is equal to or smaller than the threshold 601S, the selector 603 selects the first

step size set value 602S and outputs the first step size set value 602S as the step size 104S. From the comparison result of the comparator 602, when the absolute value of the error signal 102S exceeds the threshold 601S, the selector 603 selects the second step size set value 603S which is a step size larger than the first step size set value 602S, and outputs the second step size set value 603S as the step size 104S (step S403). In this way, in steps S402 and S403, the step size 104S is decided on the basis of the error signal 102S, the threshold 601S, the first step size set value 602S and the second step size set value 603S. The coefficient updating amount calculation unit 103 receives the error signal 102S, the step size 104S and the data 105S, performs the multiplication of these, and outputs the tap coefficient updating amount 106S (step S404). Then, the tap coefficient updating amount 106S is used in the waveform equalizer 101 to update the tap coefficient shown by (Expression 1). Here, the processes of steps S401 to S404 and the update of the tap coefficient in the waveform equalizer 101 are repeated as long as the waveform equalization is performed in the waveform equalizer 101.

The threshold 601S is set to have such a value that when the absolute value of the error signal 102S is equal to or smaller than the threshold value 601S, the waveform equalizer 101 has almost converged.

As described above, according to the waveform equalization controller of the third embodiment, the step size decision unit 601 is provided which changes the magnitude of the step size 104S according to the magnitude of the error signal 102S. Therefore, in a stage where the error is large, i.e., the waveform equalizer 101 has not being converging yet, the large step size is employed to increase the convergence speed. In a stage where the error is small, i.e., the waveform equalizer 101 has almost converged, the small step size is employed to ensure the stability at the low C/N time. Accordingly, the waveform equalization controller having a higher convergence speed and a higher stability at the low C/N time can be realized.

In this third embodiment, the step size is changed at two levels. However, it is possible that plural thresholds are input to the comparator 602 and one of step sizes at three or more levels is selected by the selector 603 according to the comparison result.

[Embodiment 4]

A waveform equalization controller according to the fourth embodiment of the present invention will be described with reference to the figures.

Figure 7 is a block diagram illustrating a structure of the waveform equalization controller according to the fourth embodiment. In figure 7, the waveform equalization

controller of the fourth embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing a transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 102 for estimating the error of the output signal 101S and outputting an error signal 102S, an error quantization unit 701 for converting the error signal 102S into a quantized error signal 701S having a value of the powers of 2 and outputting the quantized error signal 701S, and a coefficient updating amount calculation unit 702 for calculating a tap coefficient updating amount 106S on the basis of the quantized error signal 701S, a step size 104S and a data 105S to be used for the coefficient update.

Next, the operation of the waveform equalization controller according to the fourth embodiment is described with reference to the figures. The error estimation unit 102 estimates the error on the basis of the output signal 101S output by the waveform equalizer 101 to be used for the tap coefficient update, and outputs the estimated error as the error signal 102S. The error quantization unit 701 converts the error signal 102S into the quantized error signal 701S having the same sign as the signal 102S and the maximum absolute value which is equal to or smaller than the absolute value of the signal 102S among the powers of 2, and outputs the quantized error signal 701S. Figure 8

shows the relationship between the error signal 102S and the quantized error signal 701S which is obtained by converting the error signal 102S. Here, assume that when the signal 102S is "0" the signal 701S is also "0". The coefficient updating amount calculation unit 702 receives the quantized error signal 701S, the step size 104S and the data 105S. When the quantized error signal 701S taking on only the power of 2 or "0" is used, the process of multiplying the error can be replaced with the shift operation. Thus, the coefficient updating amount calculation unit 702 substitutes one multiplication and one shift operation for the process which is performed by two-time multiplication in the prior art, and outputs the tap coefficient updating amount 106S.

As described above, according to the waveform equalization controller of the fourth embodiment, the error signal 102S is converted by the error quantization unit 701 into the quantized error signal 701S having a value of the powers of 2, and the tap coefficient updating amount 106S is obtained using the quantized error signal 701S. Therefore, the multiplication can be replaced with the shift operation in the coefficient updating amount calculation unit 702. Accordingly, only one multiplier for calculating the coefficient updating amount of one tap is required, whereby the circuit scale can be reduced.

In this fourth embodiment, when the error signal 102S is to be converted into the quantized error signal 701S, the conversion as shown in figure 8 is performed. However, the error signal 102S can be converted into a quantized error signal 701S having the same sign as the error signal 102S and the minimum absolute value which is equal to or larger than the absolute value of the error signal 102S among the powers of 2. Or the error signal 102S can be converted into a quantized error signal 701S having the same sign as the error signal 102S and the absolute value which is the nearest to the absolute value of the error signal 102S among the powers of 2.

[Embodiment 5]

A waveform equalization controller according to the fifth embodiment of the present invention will be described with reference to the figures.

Figure 9 is a block diagram illustrating a structure of the waveform equalization controller according to the fifth embodiment. In figure 9, the waveform equalization controller of the fifth embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 102 for estimating the error of the output signal 101S and outputting an error signal 102S,

a data quantization unit 901 for converting a data 105S to be used for the coefficient update into a quantized data 901S having a value of the powers of 2 and outputting the quantized data 901S, and a coefficient updating amount calculation unit 902 for calculating a tap coefficient updating amount 106S on the basis of the error signal 102S, a step size 104S and the quantized data 901S.

Next, the operation of the waveform equalization controller according to the fifth embodiment is described with reference to the figures. The error estimation unit 102 estimates the error on the basis of the output signal 101S output by the waveform equalizer 101 to be used for the tap coefficient update, and outputs the estimated error as the error signal 102S. The data quantization unit 901 converts the data 105S into the quantized data 901S having the same sign as the data 105S and the maximum absolute value which is equal to or smaller than the data 105S among the powers of 2, and outputs the quantized data 901S. Figure 10 shows the relationship between the data 105S and the quantized data 901S which is obtained by converting the data 105S. Here, assume that when the data 105S is "0" the data 901S is also "0". The coefficient updating amount calculation unit 902 receives the error signal 102S, the step size 104S and the quantized data 901S. When the quantized data 901S taking on only the powers of 2 or "0"

is used, the process of multiplying the error can be replaced with the shift operation. Thus, the coefficient updating amount calculation unit 902 substitutes one multiplication and one shift operation for the process which is performed by two-time multiplication in the prior art, and outputs the tap coefficient updating amount 106S.

As described above, according to the waveform equalization controller of the fifth embodiment, the data 105S to be used for the coefficient update is converted by the data quantization unit 901 into the quantized data 901S having a value of the powers of 2, and the tap coefficient updating amount 106S is obtained using the quantized data 901S. Therefore, the multiplication can be replaced with the shift operation in the coefficient updating amount calculation unit 902. Accordingly, only one multiplier for calculating the coefficient updating amount of one tap is required, whereby the circuit scale can be reduced.

In this fifth embodiment, when the data 105S to be used for the coefficient update is to be converted into the quantized data 901S, the conversion as shown in figure 10 is performed. However, the data 105S can be converted into a quantized data 901S having the same sign as the data 105S and the minimum absolute value which is equal to or larger than the absolute value of the data 105S among the powers of 2. Or the data 105S can be converted into a quantized

data 901S having the same sign as the data 105S and the absolute value which is nearest to the absolute value of the data 105S among the powers of 2.

[Embodiment 6]

A waveform equalization controller according to the sixth embodiment of the present invention will be described with reference to the figures.

Figure 11 is a block diagram illustrating a structure of the waveform equalization controller according to the sixth embodiment. In figure 11, the waveform equalization controller of the sixth embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 102 for estimating the error of the output signal 101S and outputting an error signal 102S, a step size quantization unit 1101 for converting a step size 104S into a quantized step size 1101S having a value of powers of 2 and outputting the quantized step size 1101S, and a coefficient updating amount calculation unit 1102 for calculating a tap coefficient updating amount 106S on the basis of the error signal 102S, the quantized step size 1101S and a data 105S to be used for the coefficient update.

Next, the operation of the waveform equalization controller according to the sixth embodiment is described

with reference to the figures. The error estimation unit 102 estimates the error on the basis of the output signal 101S output by the waveform equalizer 101 to be used for the tap coefficient update, and outputs the estimated error as the error signal 102S. The step size quantization unit 1101 converts the step size 104S into the quantized step size 1101S having the maximum value which is equal to or smaller than the step size 104S among the powers of 2, and outputs the quantized step size 1101S. Figure 12 shows the relationship between the step size 104S and the quantized step size which is obtained by converting the step size 104S. Here, assume that when the step size 104S is "0" the quantized step size 1101S is also "0". The coefficient updating amount calculation unit 1102 receives the error signal 102S, the quantized step size 1101S and the data 105S. When the quantized step size 1101S taking on only the powers of 2 or "0" is used, the process of multiplying the error can be replaced with the shift operation. Therefore, the coefficient updating amount calculation unit 1102 replaces the process which is performed by the two-time multiplication in the prior art with one multiplication and one shift operation, and outputs the tap coefficient updating amount 106S.

As described above, according to the waveform equalization controller of the sixth embodiment, the step

size 104S is converted by the step size quantization unit 1101 into the quantized step size 1101S having a value of the powers of 2, and the tap coefficient updating amount 106S is obtained using the quantized step size 1101S. Therefore, in the coefficient updating amount calculation unit 1102, the multiplication can be replaced with the shift operation. Accordingly only one multiplier for calculating the coefficient updating amount of one tap is required, whereby the circuit scale can be reduced.

In this sixth embodiment, when the step size 104S is to be converted into the quantized step size 1101S, the conversion as shown in figure 12 is performed. However, the step size 104S can be converted into a quantized step size 1101S having the minimum value which is equal to or larger than the step size 104S among the powers of 2. Or the step size 104S can be converted into a quantized step size 1101S having a value which is nearest to the step size 104S among the powers of 2.

[Embodiment 7]

A waveform equalization controller according to the seventh embodiment will be described with reference to the figures.

Figure 13 is a block diagram illustrating a structure of the waveform equalization controller according to the seventh embodiment. In figure 13, the waveform

equalization controller according to the seventh embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 1303 for estimating the error of the output signal 101S and outputting an error signal 102S which is obtained by making the estimated error to "0" when the error corresponds to a predetermined range of the output signal, a coefficient update timing control unit 1301 for receiving the error signal 102S and outputting an update timing signal 1301S which controls the timing of calculation of the coefficient updating amount of the tap, and a coefficient updating amount calculation unit 1302 for calculating a tap coefficient updating amount 106S on the basis of the error signal 102S, the update timing signal 1301S, a step size 104S and a data 105S to be used for the coefficient update.

Next, the operation of the waveform equalization controller according to the seventh embodiment is described with reference to the figures.

Figure 27 is a flowchart showing the operation of the waveform equalization controller according to the seventh embodiment. Figures 14(a)-14(d) are diagrams for explaining the timing of the tap coefficient update in the waveform equalization controller of the seventh embodiment.

The error estimation unit 1303 estimates the error on the basis of the output signal 101S output by the waveform equalizer 101 to be used for the tap coefficient update, generates the error signal 102S on the basis of the estimated error, and outputs the error signal 102S (step S501). Here, the error estimation unit 1303 generates the error signal 102S on the basis of Stop&Go algorithm. As shown in figure 14(d), the coefficient update timing control unit 1301 turns the update timing signal 1301S ON at the first symbol after a predetermined symbol interval (in this case "n" symbols, "n" being an integer of 1 or more) or more from the previous coefficient update timing and when the error signal 102S is not "0". At other symbols, the update timing signal 1301S is turned OFF (step S502). The coefficient updating amount calculation unit 1302 receives the error signal 102S, the step size 104S and the data 105S only when the update timing signal 1301S is ON, then performs the multiplication of these, and outputs the tap coefficient updating amount 106S (step S503). Then, the tap coefficient updating amount 106S is used in the waveform equalizer 101 to update the tap coefficient shown by (Expression 1). Here, the processes of steps S501 to S503 and the update of the tap coefficient in the waveform equalizer 101 are repeated as long as the waveform equalization is performed in the waveform equalizer 101.

In the prior art waveform equalization controller, the coefficient updating amount calculation unit outputs the tap coefficient updating amount 106S at predetermined symbol intervals (here "n" symbols, "n" being an integer of 1 or more) as shown in figure 14(b). When the error signal 102S is generated using Stop&Go algorithm, the error signal 102S which is output by the error estimation unit 1303 takes on "0" with a probability of about 50% as shown in figure 22(b). Since the tap coefficient updating amount 106S is obtained by $-\alpha \times e(n) \times di(n)$, when the error signal 102S is "0", i.e., when $e(n)=0$, the tap coefficient updating amount becomes "0". That is, though the coefficient updating amount calculation unit outputs the tap coefficient updating amounts 106S once for every n symbols, about half of the tap coefficient updating amounts are "0". Accordingly, the substantial coefficient update interval is 2n symbols as shown in figure 14(c).

In this seventh embodiment, as shown in figure 14(d), the substantial coefficient update interval is approximately (n+1) symbols and therefore the interval is reduced about by half with relative to the prior art.

As described above, according to the waveform equalization controller of the seventh embodiment, the coefficient updating amount calculation unit 1302 comprises the coefficient update timing control unit 1301 for

controlling the timing of calculation of the tap coefficient updating amount 106S. Therefore, the substantial coefficient update interval is reduced greatly and the convergence speed of the waveform equalizer 101 can be increased.

In this seventh embodiment, the description is given of the waveform equalization controller using Stop&Go algorithm. However, the present invention is not limited to this waveform equalization controller. For example, the present invention can be also applied to a waveform equalization controller which may make the error signal 102S "0", i.e., stop the coefficient update operation in some states of the input or output signal.

In addition, the coefficient update timing control unit 1301 of the seventh embodiment is not limited to the unit which turns the update timing signal 1301S ON at the first symbol after "n" or more symbols from the previous coefficient update timing and when the error signal 102S is not "0". For example, a coefficient update timing control unit which monitors the error signal 102S thereby turning the update timing signal 1301S ON, such as a coefficient update timing control unit which turns the update timing signal 1301S ON at the second symbol after "n" or more symbols from the previous coefficient update timing and when the error signal 102S is not "0" is included

in the present invention.

In addition, in this seventh embodiment, the timing of the coefficient update is controlled by turning the update timing signal 1301S ON or OFF. However, the present invention is not limited to this. For example, the update timing for the tap coefficient can be controlled by changing the kind of an identifier included in the update timing signal 1301S. In this embodiment, "generating the update timing signal 1301S" includes turning the update timing signal 1301S ON or OFF.

[Embodiment 8]

A waveform equalization controller according to the eighth embodiment of the present invention will be described with reference to the figures.

Figure 15 is a block diagram illustrating a structure of the waveform equalization controller according to the eighth embodiment. In figure 15, the waveform equalization controller of the eighth embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 1501 for estimating the error of the output signal 101S and outputting an error signal 1502S, and a coefficient updating amount calculation unit 103 for calculating a tap coefficient updating amount 106S on the

basis of the error signal 1502S, a step size 104S, and a data 105S to be used for the coefficient update. The error estimation unit 1501 comprises an output error estimation unit 1502 for receiving the output signal 101S and outputting an output error signal 1501S, and a coefficient updating error generation unit 1503 for receiving the output error signal 1501S and the output signal 101S, reducing a partial section of the output error signal 1501S at a predetermined ratio, and outputting the error signal 1502S.

Next, the operation of the waveform equalization controller according to the eighth embodiment is described with reference to the figures. Here, the description is given taking a case where the input to the waveform equalizer is the DTV signal as an example.

Figure 28 is a flowchart showing the operation of the waveform equalization controller according to the eighth embodiment.

The output error estimation unit 1502 estimates the output error which is an error between the most likely symbol value and the output signal 101S output by the waveform equalizer 101, and generates the output error signal 1501S (step S601). The coefficient updating error generation unit 1503 receives the output error signal 1501S and the output signal 101S, generates a value of 25% of the output error signal 1501S as the error signal 1502S for the output

error signal 1501S outputting "0" according to Stop&Go algorithm as shown in figure 22(b), and outputs this value (step S602). Figure 16 shows the relationship between the output error signal 1501S and the error signal 1502S. The coefficient updating amount calculation unit 103 receives the error signal 1502S, the step size 104S and the data 105S, performs the multiplication of these, and outputs the tap coefficient updating amount 106S (step S603). Then, the tap coefficient updating amount 106S is used in the waveform equalizer 101 to update the tap coefficient shown by (Expression 1). Here, the processes of steps S601 to S603 and the update of the tap coefficient in the waveform equalizer 101 are repeated as long as the waveform equalization is performed in the waveform equalizer 101.

As described above, according to the waveform equalization controller of the eighth embodiment, the coefficient updating error generation unit 1503 for converting the output error signal into the value of 25% of the output error signal 1501S and outputting the value is provided, in place of the coefficient updating error generation unit converting the output error signal into "0" and outputting the error signal in the Stop&Go algorithm. Therefore, the error signals which can be used for updating the tap coefficient are increased in number and the convergence speed of the waveform equalizer 101 can be

increased.

In this eighth embodiment, the description is given of a case where the input is the DTV signal. However, the input is not limited to the DTV signal. Further, the ratio which is used by the coefficient updating error generation unit 1503 to convert the output error signal is not limited to 25%.

[Embodiment 9]

A waveform equalization controller according to the ninth embodiment of the present invention will be described with reference to the figures.

Figure 17 is a block diagram illustrating a structure of the waveform equalization controller according to the ninth embodiment. In figure 17, the waveform equalization controller of the ninth embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 1701 for estimating the error of the output signal 101S and outputting an error signal 1701S, a coefficient updating amount calculation unit 103 for calculating a tap coefficient updating amount 106S on the basis of the error signal 1701S, a step size 104S and a data 105S to be used for the coefficient update, and an error rate measuring circuit 1703 for measuring an error rate of

the data on the basis of the output signal 101S and outputting the error rate as an error rate signal 1702S. The error estimation unit 1701 comprises an output error estimation unit 1502 for receiving the output signal 101S and outputting an output error signal 1501S, and a coefficient updating error generation unit 1702 for receiving the output error signal 1501S, the output signal 101S and the error rate signal 1702S and outputting the error signal 1701S.

Next, the operation of the waveform equalization controller according to the ninth embodiment is described with reference to the figures. Here, the description is given taking a case where the input to the waveform equalizer 101 is the DTV signal as an example.

Figure 29 is a flowchart showing the operation of the waveform equalization controller according to the ninth embodiment.

The output error estimation unit 1502 estimates the output error as the error between the most likely symbol value and the output signal 101S output by the waveform equalizer 101, and generates the output error signal 1501S (step S701). The error rate measuring circuit 1703 turns the error rate signal 1702S ON when the error rate indicating a rate of the error included in the output signal 101S from the waveform equalizer 101 becomes equal to or larger than a predetermined value, for example 10%, and turns the error

rate signal 1702S OFF in other cases (step S702). Here, the error rate measuring circuit 1703 measures the error rate using data for ECC included in the output signal 101S, bits for ECC or the like.

The coefficient updating error generation unit 1702 receives the output error signal 1501S, the output signal 101S and the error rate signal 1702S, and when the error rate signal 1702S is ON it outputs the same signal as the error signal as shown in figure 22(b) on the basis of Stop&Go algorithm like in the prior art. When the error rate signal 1702S is OFF, the output error signal 1501S shows a nearly correct value. Therefore, the conversion on the basis of Stop&Go algorithm is not performed and the output error signal 1501S is output as it is as the error signal 1701S (step S703). Figure 18 shows the relationship between the output error signal 1501S and the error signal 1701S in the case where the error rate signal 1702S is OFF. The coefficient updating amount calculation unit 103 receives the error signal 1701S, the step size 104S and the data 105S, performs the multiplication of these, and outputs the tap coefficient updating amount 106S (step S704). Then, the tap coefficient updating amount 106S is used in the waveform equalizer 101 to update the tap coefficient shown by (Expression 1). Here, the processes of steps S701 to S704 and the update of the tap coefficient in the waveform

equalizer 101 are repeated as long as the waveform equalization is performed in the waveform equalizer 101.

As described above, according to the waveform equalization controller of the ninth embodiment, the error rate measuring circuit 1703 which turns the error rate signal 1702S ON or OFF according to the error rate of the output signal 101S in the Stop&Go algorithm, and the coefficient updating error generation unit 1702 which outputs the error signal 1701S which is obtained by converting part of the output error signal 1501S into "0" when the error rate signal 1702S is ON and outputs the output error signal 1501S as it is without converting the part into "0" when the error rate signal is OFF are provided. Therefore, the error signals 1701S which can be used for the tap coefficient update are increased in number and therefore the convergence speed of the waveform equalizer 101 can be improved.

In this ninth embodiment, the description is given of the case where the input is the DTV signal. However, the input is not limited to the DTV signal.

In addition, the threshold of the error rate at which the error rate measuring circuit 1703 switches the error rate signal 1702S between ON and OFF is set at 10% in this embodiment. However, the threshold is not limited to this value.

Further, when the error rate signal 1702S is ON, the coefficient updating error generation unit 1702 generates the error signal 1701S on the basis of Stop&Go algorithm in this embodiment. However, the present invention is not limited to this. For example, the coefficient updating error generation unit can output the error signal 1502S as shown in figure 16(b) of the eighth embodiment when the error rate signal 1702S is ON. As long as the error signal 1701S output by the coefficient updating error generation unit 1702 when the error rate signal 1702S is ON is not the same as the output error signal 1501S, i.e., is a signal obtained by attenuating the output error signal 1501S in a predetermined range or at a predetermined ratio or making the output error signal 1501S "0", this is included in the scope of the present invention.

In addition, in this ninth embodiment, the error rate signal 1702S is generated by the error rate measuring circuit 1703 as ON or OFF. However, the present invention is not limited to this. For example, whether the error rate is equal to or more than the predetermined value or not can be shown by changing the kind of an identifier included in the error rate signal 1702S. In this embodiment, "generating the error rate signal 1702S" includes turning the error rate signal 1702S ON or OFF.

Further, when the output signal 101S of the waveform

equalizer 101 is input to a Forward Error Correction Unit (not shown), an error rate measuring circuit included in the Forward Error Correction Unit can be used as the error rate measuring circuit 1703 according to the ninth embodiment.

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WHAT IS CLAIMED IS:

1. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal;

a step size decision unit for receiving the error signal and a step size upper limit value and a step size lower limit value being an upper limit value and a lower limit value of a step size as a step for the update of the tap coefficient, adaptively generating a step size which corresponds to the error signal in a range of the step size upper limit value or smaller and the step size lower limit value or larger, and outputting the generated step size; and

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, the step size and a data to be used for the tap coefficient update.

2. The waveform equalization controller of Claim 1 wherein the step size decision unit comprises:

a multiplier for squaring the error signal to generate

a square error;

a square error storage unit for containing the square error which has been generated at a previous tap coefficient update;

a subtracter for generating a difference between square errors, which is a difference between the square error output by the multiplier and the square error stored in the square error storage unit generated at the previous tap coefficient update;

a first comparator for comparing the square error with a first threshold;

a second comparator for comparing the square error with a second threshold;

a third comparator for comparing an absolute value of the difference between square errors with a third threshold;

a step size storage unit for containing a step size which has been used at the previous tap coefficient update; and

a step size increasing/decreasing unit for receiving the step size which has been stored in the step size storage unit, an output of the first comparator, an output of the second comparator, an output of the third comparator, the step size upper limit value and the step size lower limit value, and generating a step size which is to be used for this tap coefficient update.

3. The waveform equalization controller of Claim 2 wherein

the second threshold is such a value that when the square error is larger than the value an operation of the waveform equalizer is trending toward divergence;

the first threshold is such a value that when the square error is smaller than the value the operation of the waveform equalizer is either converging or has converged;

the third threshold is such a value that in the case where the square error is smaller than the first threshold, when an absolute value of the difference between square errors is larger than the third threshold the operation of the waveform equalizer is converging and when the absolute value is equal to or smaller than the third threshold the operation of the waveform equalizer has converged; and

the step size increasing/decreasing unit decreases the step size by a predetermined amount when it is judged from comparison results of the first to third comparators that the square error is larger than the second threshold,

decreases the step size by a predetermined amount when the square error is smaller than the first threshold and the absolute value of the difference between square errors is equal to or smaller than the third threshold,

increases the step size by a predetermined amount when the square error is smaller than the first threshold and

the absolute value of the difference between square errors is larger than the third threshold, and

does not change the step size in other cases.

4. The waveform equalization controller of Claim 2 wherein

the second threshold is such a value that when the square error is larger than the value an operation of the waveform equalizer is trending toward divergence;

the first threshold is such a value that when the square error is smaller than the value the operation of the waveform equalizer is either converging or has converged;

the third threshold is such a value that in the case where the square error is smaller than the first threshold, when an absolute value of the difference between square errors is larger than the third threshold the operation of the waveform equalizer is converging and when the absolute value is equal to or smaller than the third threshold the operation of the waveform equalizer has converged; and

the step size increasing/decreasing unit decreases the step size at a predetermined rate when it is judged from comparison results of the first to third comparators that the square error is larger than the second threshold,

decreases the step size at a predetermined rate when the square error is smaller than the first threshold and the absolute value of the difference between square errors

is equal to or smaller than the third threshold,

increases the step size at a predetermined rate when the square error is smaller than the first threshold and the absolute value of the difference between square errors is larger than the third threshold, and

does not change the step size in other cases.

5. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal;

a signal judgement unit for judging whether a probability of a judgement error in the error estimation for the output signal is larger or smaller, and outputting a judgement signal;

a step size decision unit for receiving the judgement signal and outputting a value according to the judgement signal as a step size which is a step for the update of the tap coefficient; and

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis

of the error signal, the step size, and a data to be used for the tap coefficient update.

6. The waveform equalization controller of Claim 5 wherein

the signal judgement unit outputs three kinds of the judgement signal of:

the judgement signal indicating that the output signal is known;

the judgement signal indicating that the probability of the judgement error for the output signal is smaller; and

the judgement signal indicating that the probability of the judgement error for the output signal is larger.

7. The waveform equalization controller of Claim 6 wherein

the step size decision unit outputs a first step size set value as the step size when the judgement signal indicates that the output signal is known,

outputs a second step size set value which is smaller than the first step size set value when the judgement signal indicates that the probability of the judgement error for the output signal is smaller, and

outputs a third step size set value which is smaller than the second step size set value when the judgement signal indicates that the probability of the judgement error for

the output signal is larger.

8. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit for estimating an error of the output signal of the waveform equalizer from the output signal, and outputting an error signal;

a step size decision unit for receiving the error signal, a threshold and plural step size set values, and deciding a step size as a step for the update of the tap coefficient; and

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, the step size and a data to be used for the tap coefficient update.

9. The waveform equalization controller of Claim 8 wherein

the plural step size set values are a first step size set value and a second step size set value which is larger than the first step size set value, and

the step size decision unit comprises:

a comparator for comparing an absolute value of the

error signal with the threshold; and

a selector for selecting one of the first step size set value and the second step size set value on the basis of a comparison result output by the comparator, and outputting the selected step size as the step size.

10. The waveform equalization controller of Claim 9 wherein

the threshold value is such a value that when the absolute value of the error signal is equal to or smaller than the threshold the waveform equalizer has nearly converged; and

the step size decision unit outputs the first step size set value as the step size when the absolute value of the error signal is equal to or smaller than the threshold, and outputs the second step size set value as the step size when the absolute value of the error signal exceeds the threshold.

11. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit for estimating an error of an

output signal of the waveform equalizer from the output signal, and outputting an error signal;

an error quantization unit for converting the error signal into a quantized error signal having a value of powers of 2, and outputting the quantized error signal; and

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the quantized error signal, the step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update.

12 The waveform equalization controller of Claim 11 wherein

the error quantization unit converts the error signal into the quantized error signal having the same sign as the error signal and a maximum absolute value among the powers of 2, which is equal to or smaller than an absolute value of the error signal, and outputting the quantized error signal.

13. The waveform equalization controller of Claim 11 wherein

the error quantization unit converts the error signal into the quantized error signal having the same sign as the error signal and a minimum absolute value among the powers

of 2, which is equal to or larger than an absolute value of the error signal, and outputting the quantized error signal.

14. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal;

a data quantization unit for converting a data to be used for the tap coefficient update into a quantized data having a value of powers of 2, and outputting the quantized data; and

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and the quantized data.

15. The waveform equalization controller of Claim 14 wherein

the data quantization unit converts the data to be used for the tap coefficient update into a quantized data having

the same sign as the data to be used for the tap coefficient update and a maximum absolute value among the powers of 2, which is equal to or smaller than an absolute value of the data to be used for the tap coefficient update, and outputting the quantized date.

16. The waveform equalization controller of Claim 14 wherein

the data quantization unit converts the data to be used for the tap coefficient update into a quantized data having the same sign as the data to be used for the tap coefficient update and a minimum absolute value among the powers of 2, which is equal to or larger than an absolute value of the data to be used for the tap coefficient update, and outputting the quantized data.

17. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal;

a step size quantization unit for converting a step size

as a step for the update of the tap coefficient into a quantized step size having a value of powers of 2, and outputting the quantized step size; and

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, the quantized step size and a data to be used for the tap coefficient update.

18. The waveform equalization controller of Claim 17 wherein

the step size quantization unit converts the step size into the quantized step size having a maximum value among the powers of 2, which is equal to or smaller than the step size, and outputs the quantized step size.

19. The waveform equalization controller of Claim 17 wherein

the step size quantization unit converts the step size into the quantized step size having a minimum value among the powers of 2, which is equal to or larger than the step size, and outputting the quantized step size.

20. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm,

and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal which is obtained by making the estimated error 0 when the estimated error is an error corresponding to a predetermined range of the output signal;

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update; and

a coefficient update timing control unit for receiving the error signal and outputting a update timing signal which controls a timing when the coefficient updating amount calculation unit calculates the tap coefficient updating amount at intervals of plural symbols.

21. The waveform equalization controller of Claim 20 wherein

the coefficient update timing control unit controls the timing of the coefficient updating amount calculation unit calculating the tap coefficient updating amount to be at a first symbol after an interval of predetermined symbols

or more from a previous timing and when the error signal is not 0.

22. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit comprising an output error estimation unit for receiving an output signal of the waveform equalizer and outputting an output error signal, and a coefficient updating error generation unit for receiving the output error signal and the output signal and outputting an error signal which is obtained by reducing a partial section of the output error signal at a predetermined rate; and

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a date to be used for the tap coefficient update.

23. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm

and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error rate measuring circuit for receiving an output signal of the waveform equalizer and generating an error rate signal which indicates a rate of an error included in the output signal;

an error estimation unit comprising an output error estimation unit for receiving the output signal of the waveform equalizer and outputting an output error signal, and a coefficient updating error generation unit for receiving the output error signal, the output signal and the error rate signal and outputting an error signal; and

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update.

24. The waveform equalization controller of Claim 23 wherein

the coefficient updating error generation unit outputs the same value as the output error signal, as the error signal, when it is detected from the error rate signal that the rate of the error included in the output signal is smaller than a predetermined rate.

25. A waveform equalization control method for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprising:

an error estimation step of estimating an error of an output signal of the waveform equalizer from the output signal, and generating an error signal;

a step size decision step of adaptively deciding a step size in a range of a step size upper limit value as an upper limit value of a step size which is a step for the update of the tap coefficient or smaller, and a step size lower limit value as a lower limit value of the step size or larger, on the basis of the error signal; and

a coefficient updating amount calculation step of calculating a tap coefficient updating amount on the basis of the error signal, the step size and a data to be used for the tap coefficient update.

26. The waveform equalization control method of Claim 25 wherein

the step size decision step comprises:

a multiplication step of squaring the error signal to generate a square error;

a subtraction step of generating a difference between square errors, which is a difference between the square error generated at a previous tap coefficient update and the square error generated in the multiplication step;

a first comparison step of comparing the square error with a first threshold;

a second comparison step of comparing the square error with a second threshold;

a third comparison step of comparing an absolute value of the difference between square errors with a third threshold; and

a step size generation step of generating a step size which is to be used for this tap coefficient update on the basis of the step size which has been used at the previous tap coefficient update, a comparison result in the first comparison step, a comparison result in the second comparison step, a comparison result in the third comparison step, the step size upper limit value and the step size lower limit value.

27. A waveform equalization control method for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprising:

a step of estimating an error of an output signal of

the waveform equalizer from the output signal, and generating an error signal;

a step of judging whether a probability of a judgement error in the error estimation for the output signal is larger or smaller, and generating a judgement signal;

a step of deciding a step size which is a step for the update of the tap coefficient on the basis of the judgement signal; and

a step of calculating a tap coefficient updating amount on the basis of the error signal, the step size, and a data to be used for the tap coefficient update.

28. A waveform equalization control method for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprising:

an error estimation step of estimating an error of the output signal of the waveform equalizer from the output signal, and generating an error signal;

a step size decision step of deciding a step size as a step for the update of the tap coefficient on the basis of the error signal, a threshold and plural step size set values; and

a coefficient updating amount calculation step of calculating a tap coefficient updating amount on the basis

of the error signal, the step size and a data to be used for the tap coefficient update.

29. The waveform equalization control method of Claim 28 wherein

the plural step size set values are a first step size set value and a second step size set value which is larger than the first step size set value, and

the step size decision step comprises:

a comparison step of comparing an absolute value of the error signal with the threshold; and

a selection step of selecting one of the first step size set value and the second step size set value as the step size on the basis of a comparison result in the comparison step.

30. A waveform equalization control method for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprising:

an error estimation step of estimating an error of an output signal of the waveform equalizer from the output signal, and generating an error signal which is obtained by making the estimated error 0 when the estimated error is an error corresponding to a predetermined range of the

output signal;

a coefficient update timing control step of generating an update timing signal which controls a timing of calculating the tap coefficient updating amount at intervals of plural symbols on the basis of the error signal; and

a coefficient updating amount calculation step of calculating a tap coefficient updating amount at the timing controlled by the update timing signal on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update.

31. The waveform equalization control method of Claim 30 wherein

the update timing signal is generated for controlling the timing of calculating the tap coefficient updating amount in the coefficient update timing control step to be at a first symbol after an interval of predetermined symbols or more from a previous timing and when the error signal is not 0.

32. A waveform equalization control method for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of

an input signal on the basis of LMS algorithm comprising:

a step of estimating an output error from an output signal of the waveform equalizer and generating an output error signal;

a step of generating an error signal which is obtained by reducing a partial section of the output error signal at a predetermined rate on the basis of the output error signal and the output signal; and

a step of calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a date to be used for the tap coefficient update.

33. A waveform equalization control method for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprising:

an output error estimation step of estimating an output error from an output signal of the waveform equalizer, and generating an output error signal;

an error rate signal generation step of generating an error rate signal which indicates a rate of an error included in the output signal of the waveform equalizer;

a coefficient updating error generation step of generating an error signal to be used for the update of the

tap coefficient on the basis of the output error signal, the output signal and the error rate signal; and

a coefficient updating amount calculation step of calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update.

34. The waveform equalization control method of Claim 33 wherein

when it is detected from the error rate signal in the coefficient updating error generation step that the rate of the error included in the output signal is smaller than a predetermined rate, the same value as the output error signal is generated as the error signal.

ABSTRACT OF THE DISCLOSURE

The present invention provides a waveform equalization controller which combines a follow-up property in the case where the distortion is varied and a higher convergence speed at the initial operation, and a higher stability at the low C/N time, and realizes a high performance and a low cost in a waveform equalizer. The waveform equalization controller which comprises a waveform equalizer 101 for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient comprises an error estimation unit 102 for estimating an error signal 102S from an output signal 101S of the waveform equalizer 101 and outputting the error signal 102S; a step size decision unit 104 for generating a step size 104S having an arbitrary size and outputting the step size 104S; and a coefficient updating amount calculation unit 103 for calculating a tap coefficient updating amount 106S on the basis of the error signal 102S, the step size 104S and a data 105S to be used for the tap coefficient update.

0005504 - 020696

Fig.1

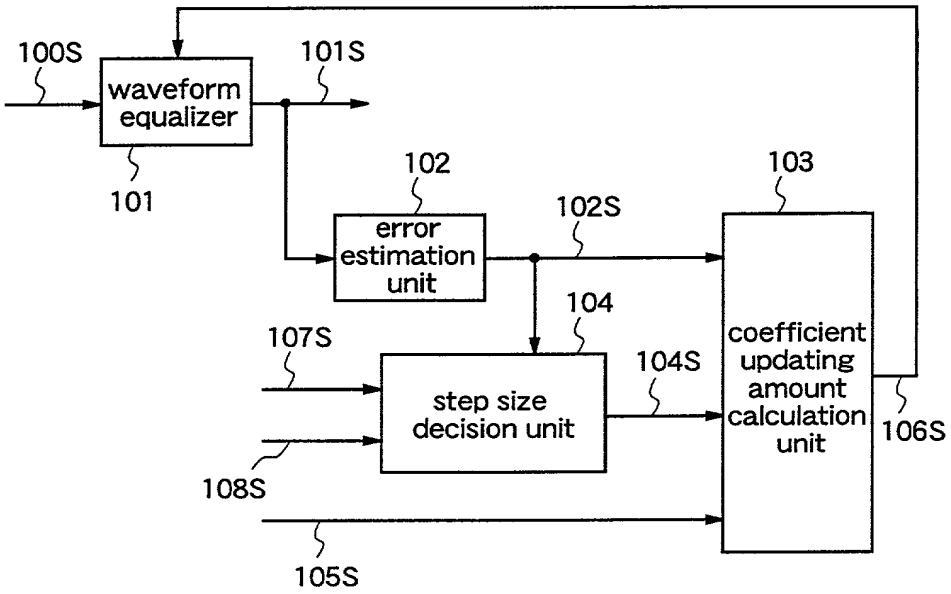

100S
waveform equalizer
101S
101
102
error estimation unit
102S
103
104
107S
step size decision unit
104S
coefficient updating amount calculation unit
106S
108S
105S

Fig.2

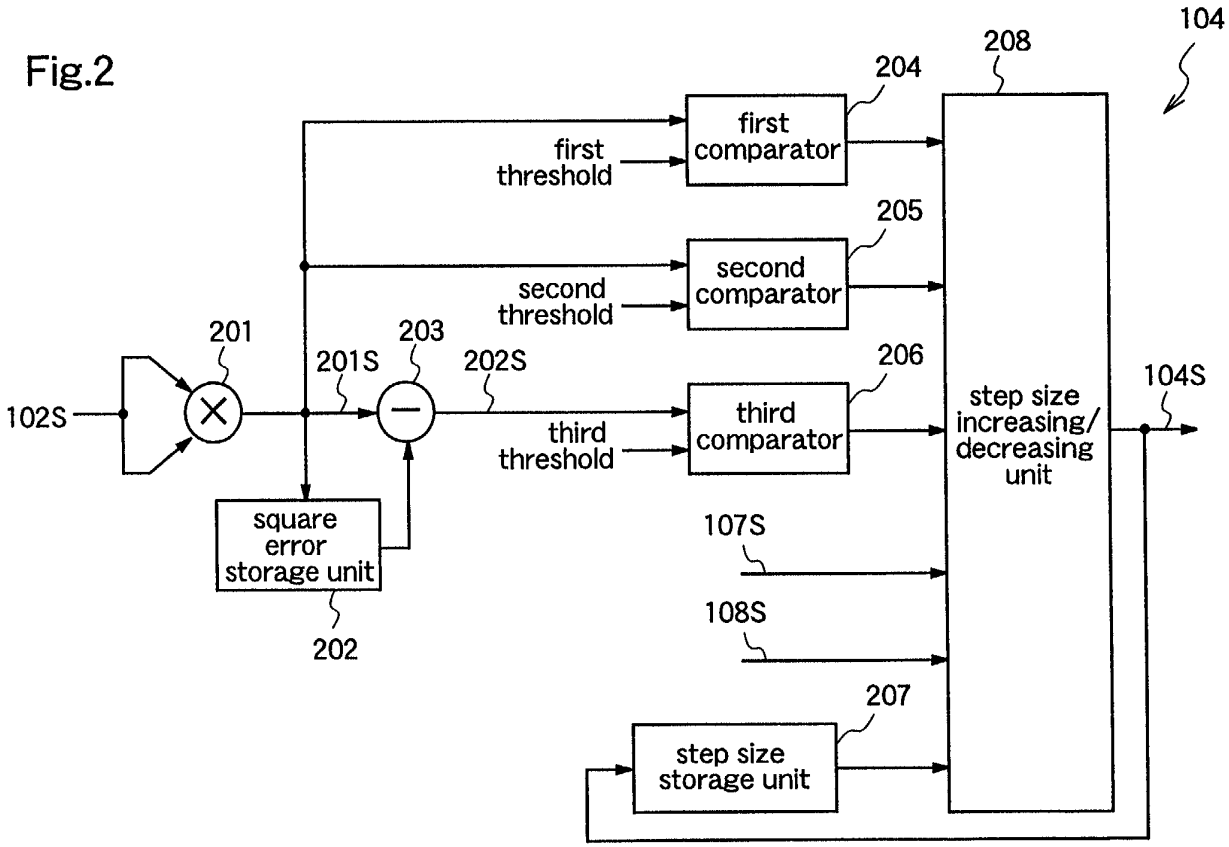

104
208
204
first comparator
first threshold
205
second comparator
second threshold
206
third comparator
third threshold
step size increasing/ decreasing unit
104S
102S
201
201S
203
202S
square error storage unit
202
107S
108S
207
step size storage unit

Fig.3

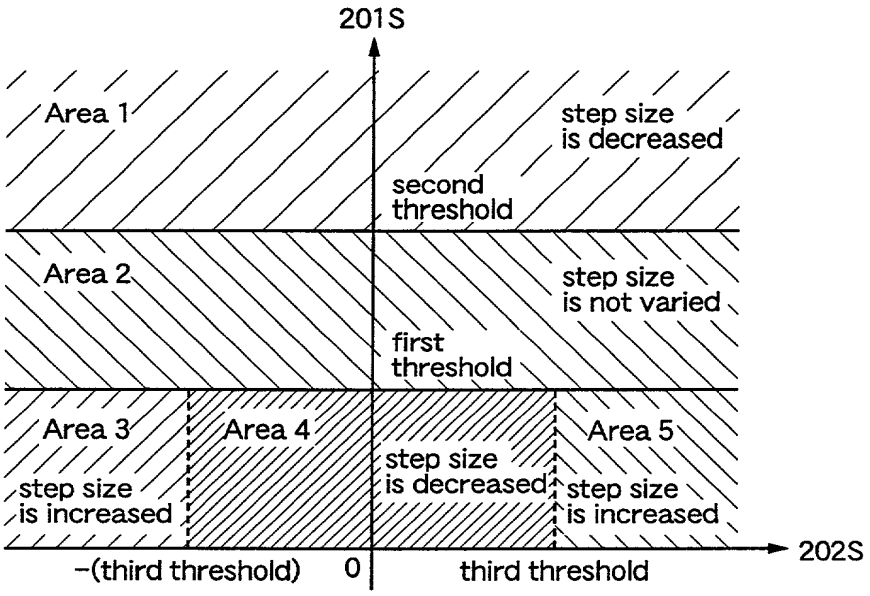

201S
Area 1
step size
is decreased
second
threshold
Area 2
step size
is not varied
first
threshold
Area 3
Area 4
Area 5
step size
is increased
step size
is decreased
step size
is increased
202S
−(third threshold)
0
third threshold

Fig.4

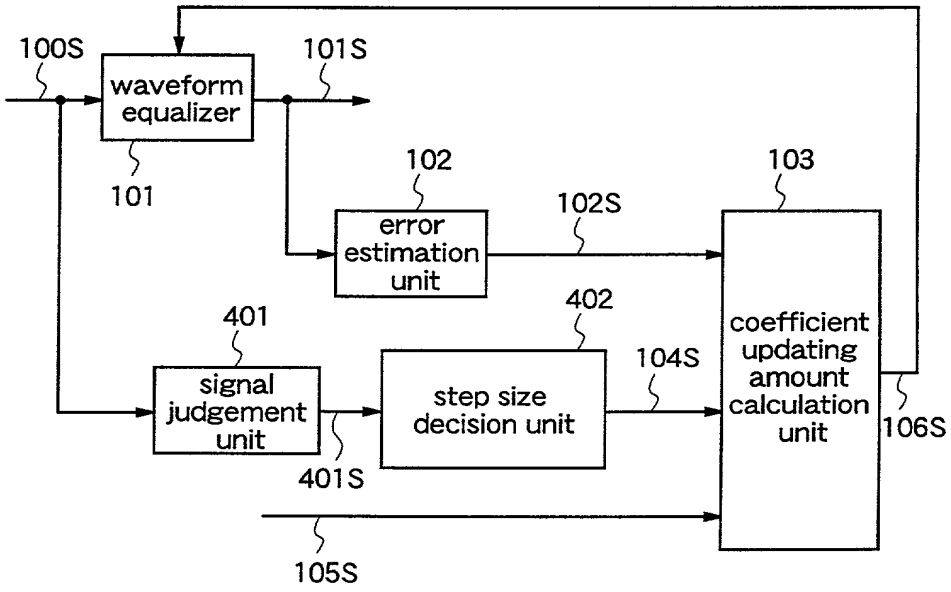

100S
waveform
equalizer
101S
101
102
error
estimation
unit
102S
103
coefficient
updating
amount
calculation
unit
106S
401
signal
judgement
unit
401S
402
step size
decision unit
104S
105S

Fig.5

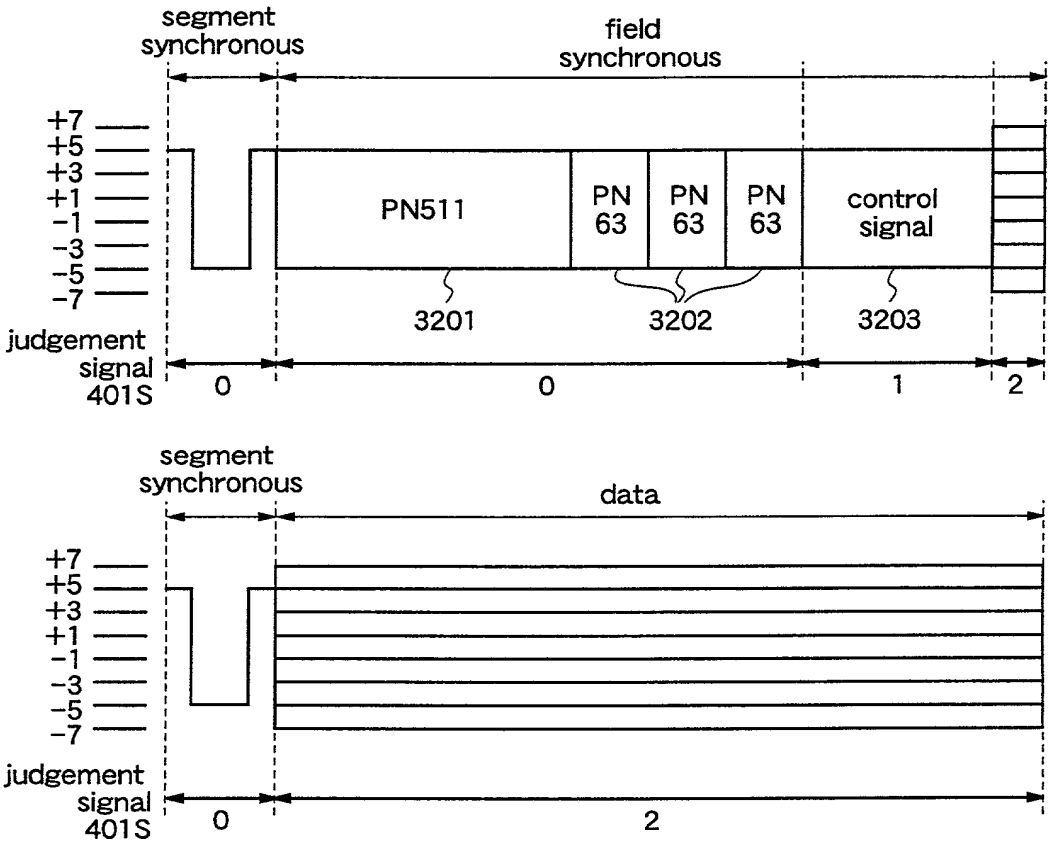

segment synchronous
field synchronous
+7
+5
+3
+1
−1
−3
−5
−7
PN511
PN 63
PN 63
PN 63
control signal
3201
3202
3203
judgement signal 401S
0
0
1
2
segment synchronous
data
+7
+5
+3
+1
−1
−3
−5
−7
judgement signal 401S
0
2

Fig.6

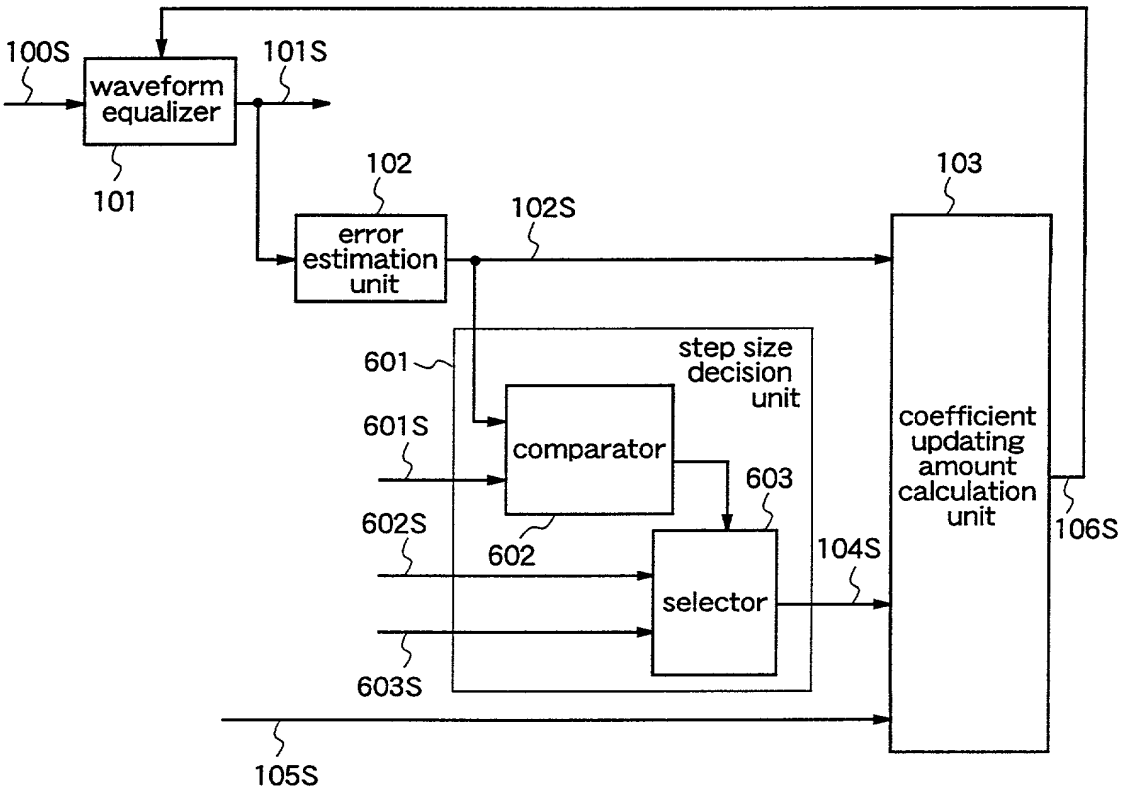

100S
waveform equalizer
101S
101
102
error estimation unit
102S
103
step size decision unit
601
601S
comparator
603
602S
602
104S
selector
603S
coefficient updating amount calculation unit
106S
105S

Fig.7

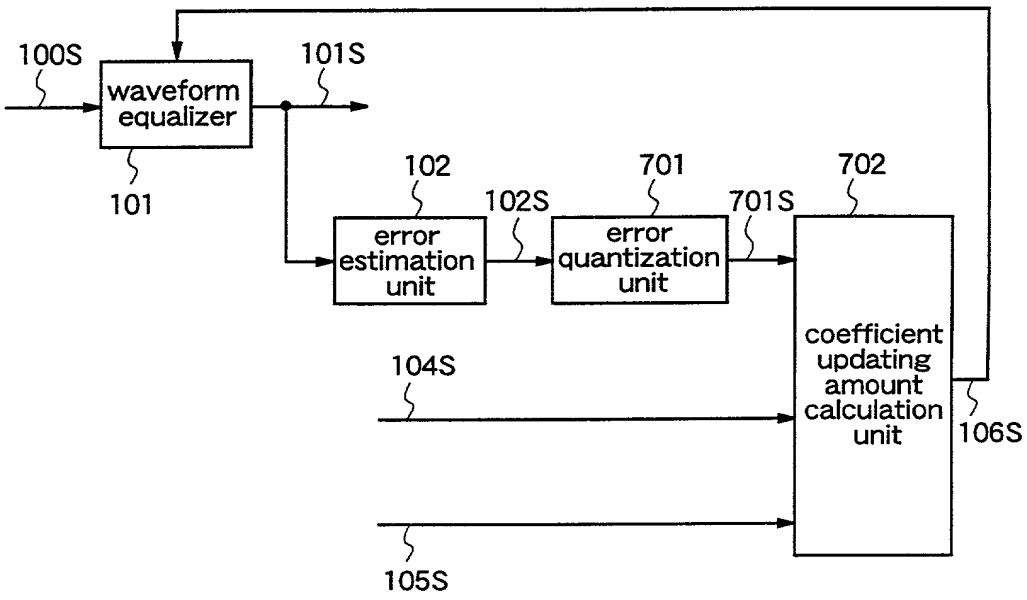

100S
waveform equalizer
101S
101
102
102S
error estimation unit
701
error quantization unit
701S
702
coefficient updating amount calculation unit
106S
104S
105S

Fig.8

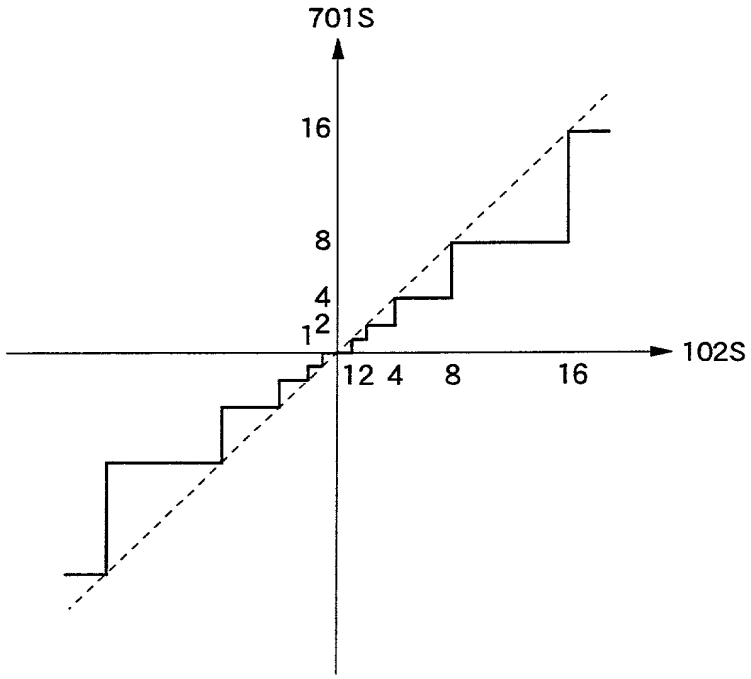

701S
16
8
4
2
1
102S
1 2 4 8 16

Fig.9

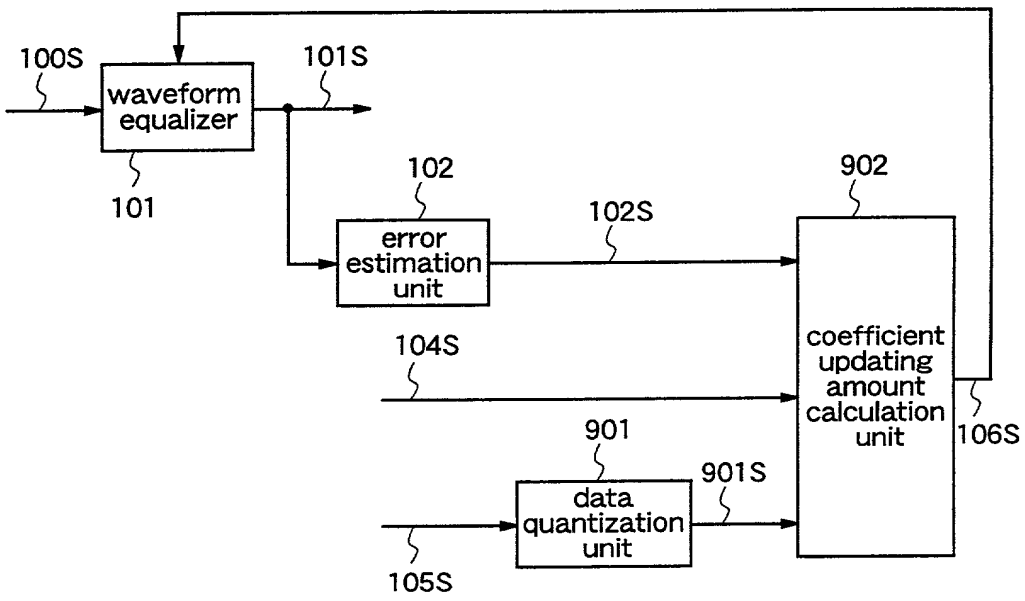

100S
waveform equalizer
101S
101
102
error estimation unit
102S
902
coefficient updating amount calculation unit
106S
104S
901
data quantization unit
901S
105S

Fig.10

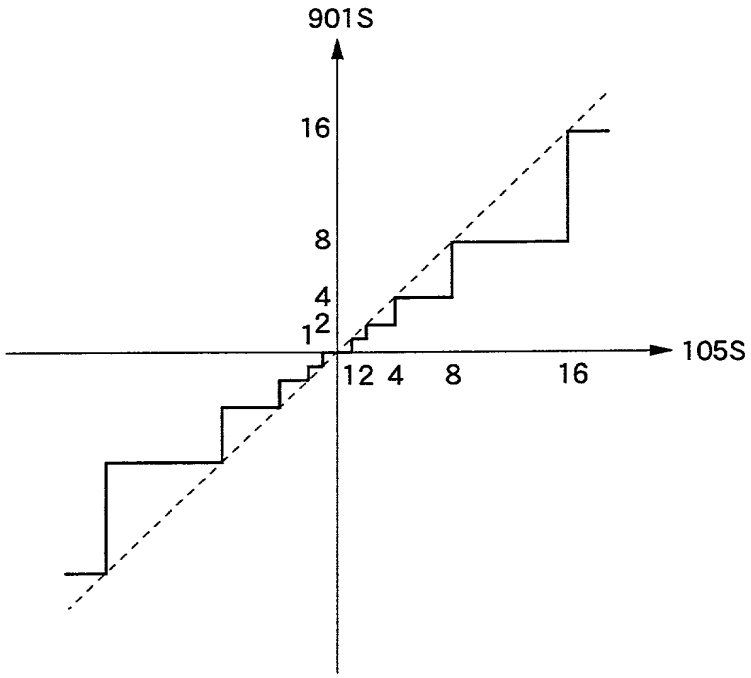

901S
16
8
4
2
1
105S
1 2 4 8 16

Fig.11

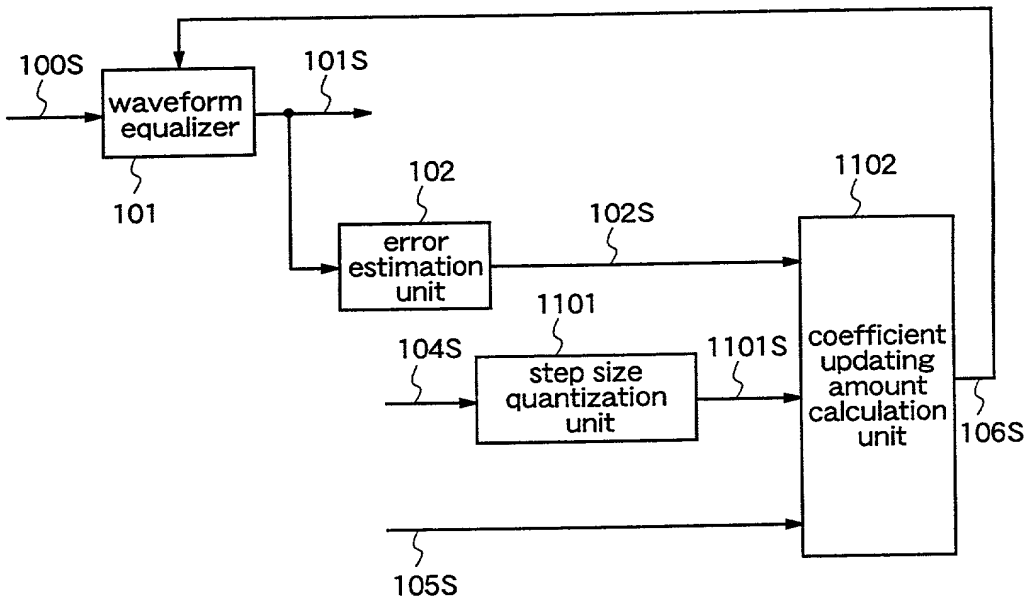

100S
waveform equalizer
101S
101
102
error estimation unit
102S
1102
1101
104S
step size quantization unit
1101S
coefficient updating amount calculation unit
106S
105S

Fig.12

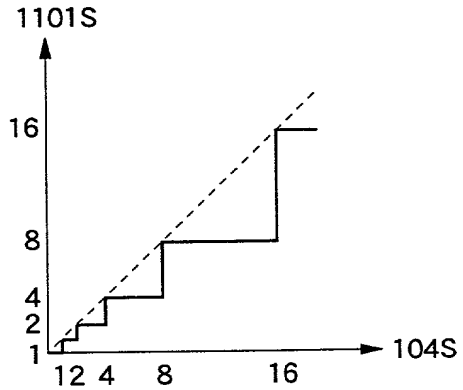

1101S
16
8
4
2
1
1 2 4 8 16
104S

Fig.13

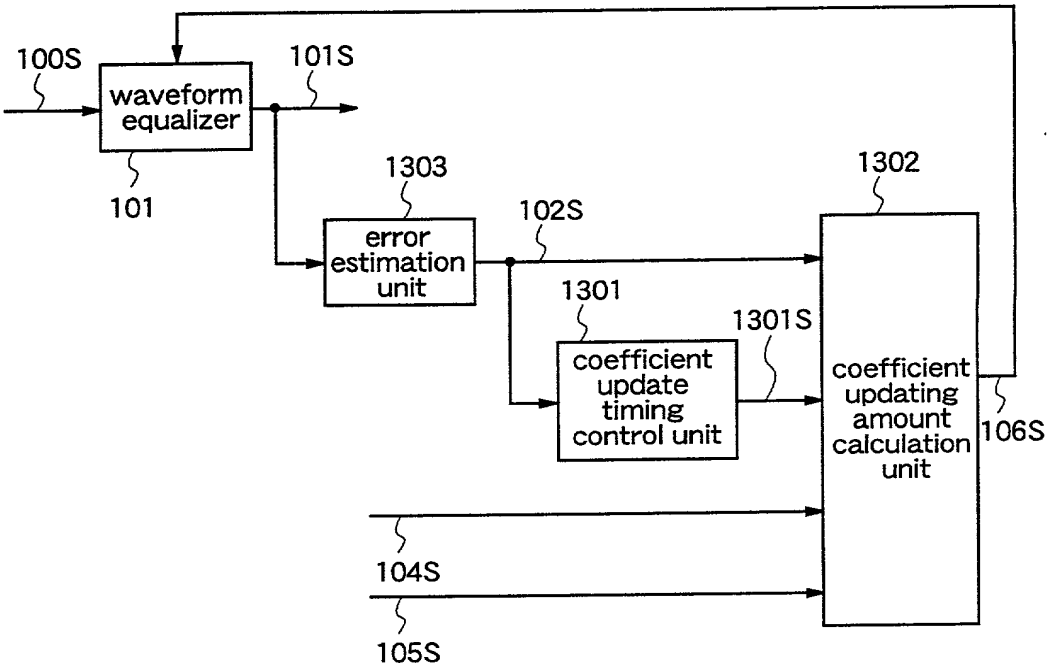

100S
waveform equalizer
101S
101
1303
error estimation unit
102S
1302
1301
1301S
coefficient update timing control unit
coefficient updating amount calculation unit
106S
104S
105S

Fig.14 (a)
error signal 102S

Fig.14 (b)
prior art coefficient update timing

Fig.14 (c)
prior art coefficient update interval timing for the error signal 102s of other than 0

Fig.14 (d)
coefficient update timing of the present invention

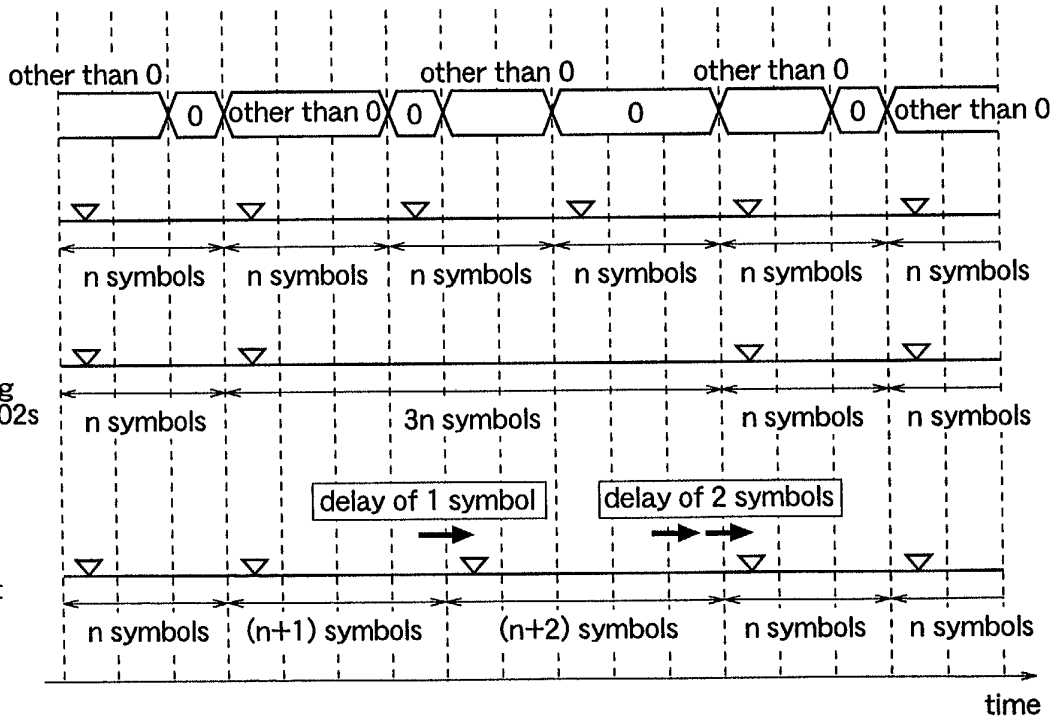


Fig.15

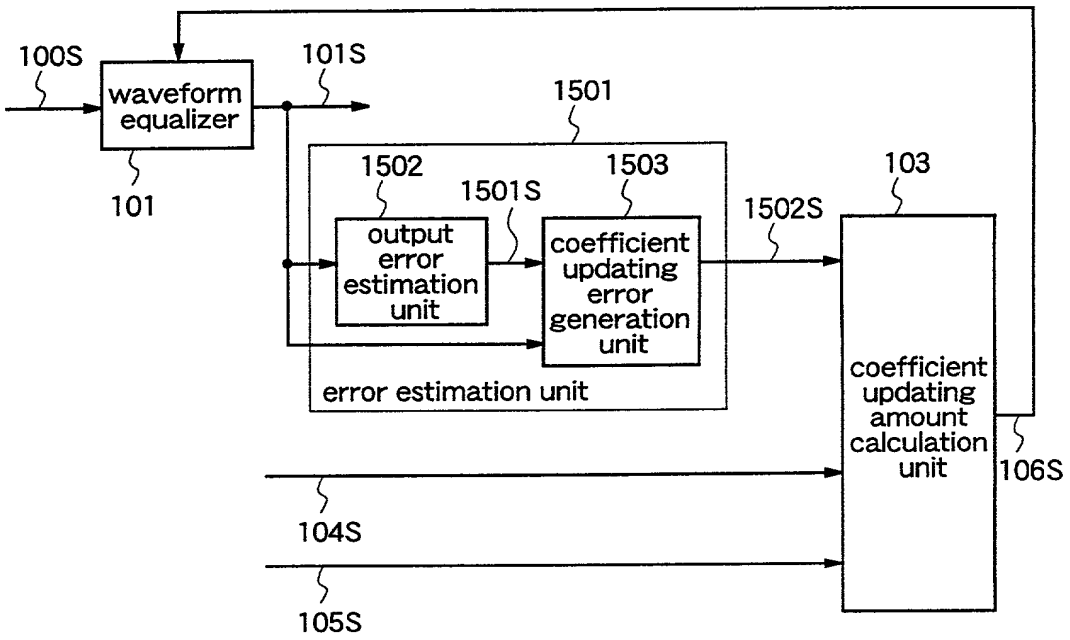


Fig.16 (a)

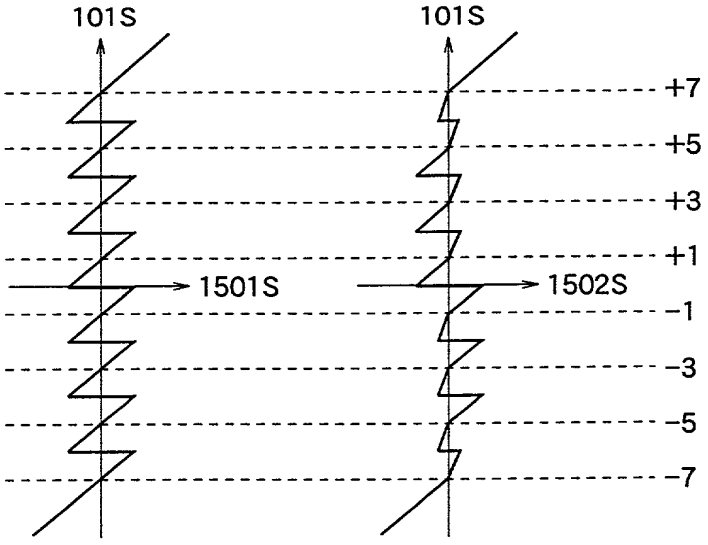


Fig.16 (b)

Fig.17

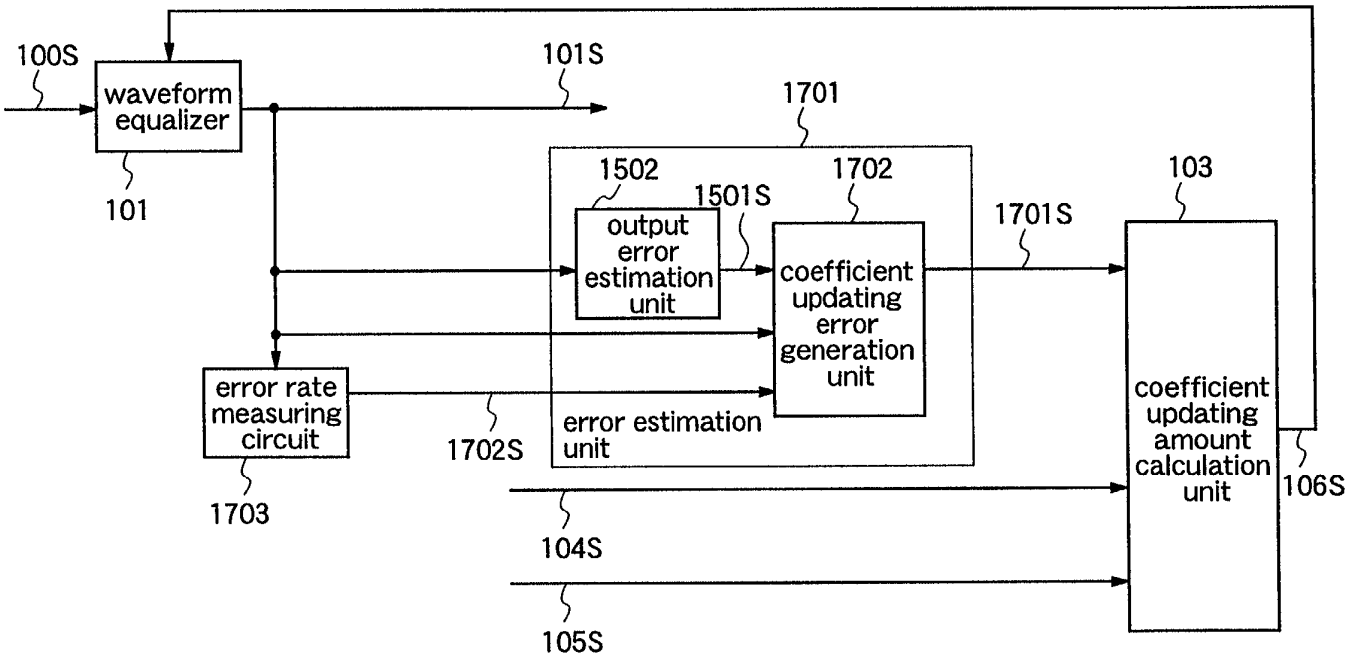

100S
waveform equalizer
101
101S
1701
1502
1501S
1702
output error estimation unit
coefficient updating error generation unit
error estimation unit
1701S
103
error rate measuring circuit
1703
1702S
104S
105S
coefficient updating amount calculation unit
106S

Fig.18 (a)

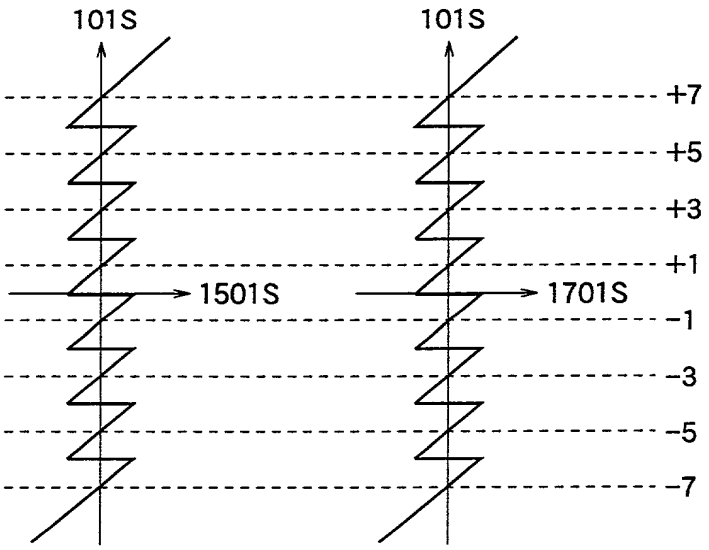


Fig.18 (b)

Fig.19 Prior Art

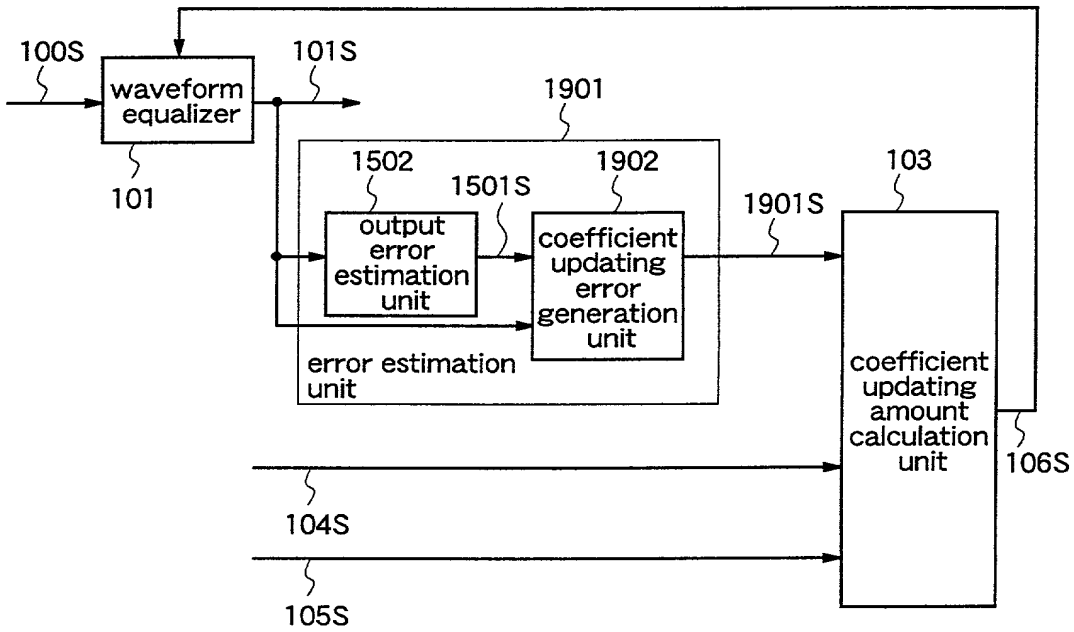


Fig.20

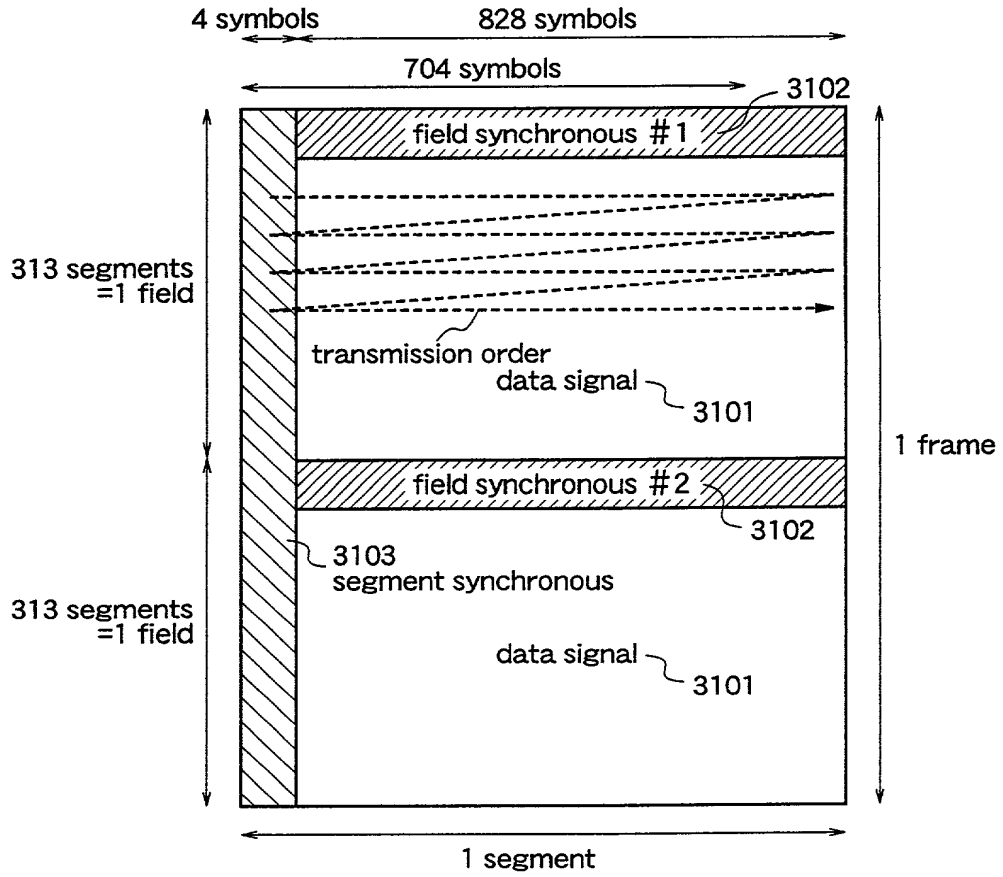
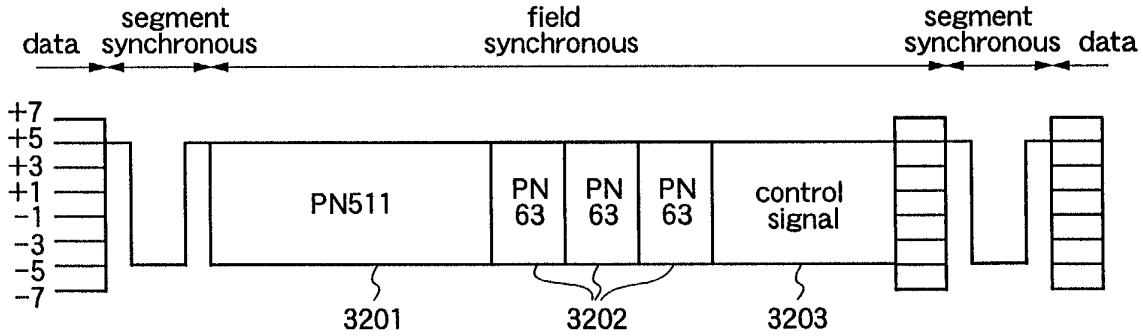

4 symbols
828 symbols
704 symbols
3102
field synchronous #1
313 segments
=1 field
transmission order
data signal
3101
1 frame
field synchronous #2
3102
3103
segment synchronous
313 segments
=1 field
data signal
3101
1 segment

Fig.21


data
segment synchronous
field synchronous
segment synchronous
data
+7
+5
+3
+1
-1
-3
-5
-7
PN511
PN 63
PN 63
PN 63
control signal
3201
3202
3203

Prior Art

Fig.22 (a)

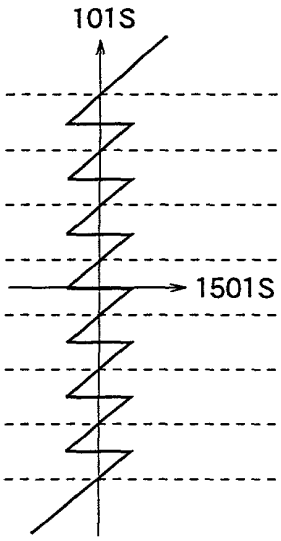


Fig.22 (b)

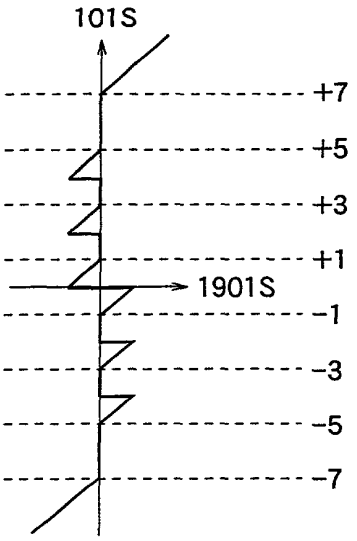


Fig.23

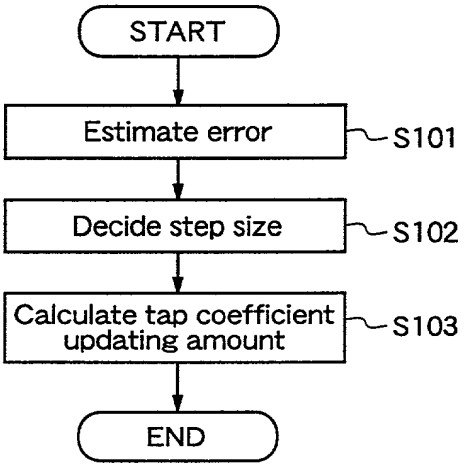

START
Estimate error
S101
Decide step size
S102
Calculate tap coefficient updating amount
S103
END

Fig.24

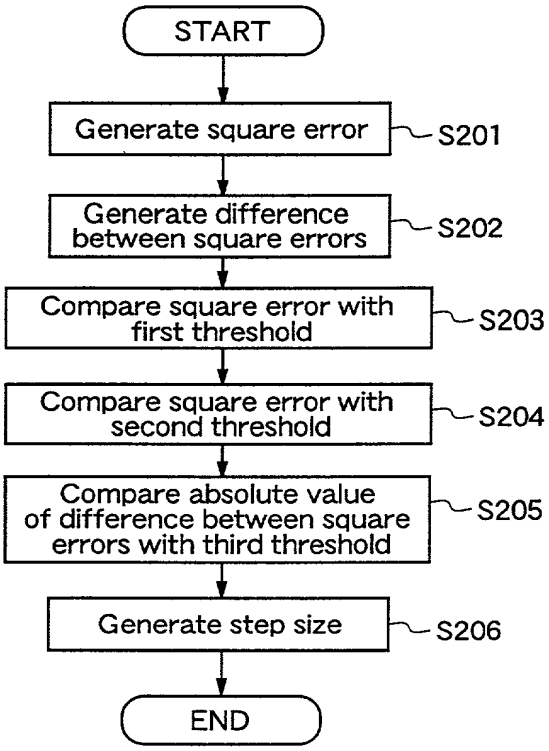

START
Generate square error
S201
Generate difference between square errors
S202
Compare square error with first threshold
S203
Compare square error with second threshold
S204
Compare absolute value of difference between square errors with third threshold
S205
Generate step size
S206
END

Fig.25

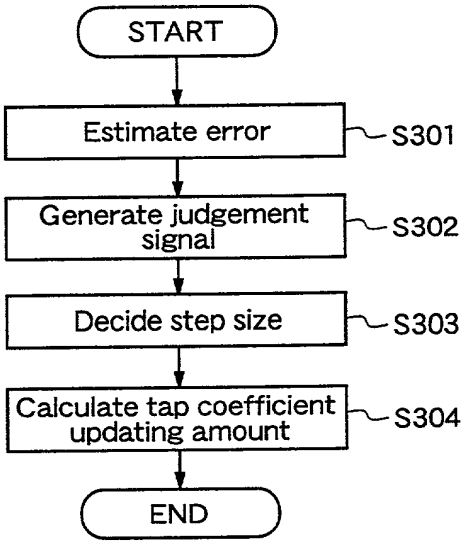

START
Estimate error
S301
Generate judgement signal
S302
Decide step size
S303
Calculate tap coefficient updating amount
S304
END

Fig.26

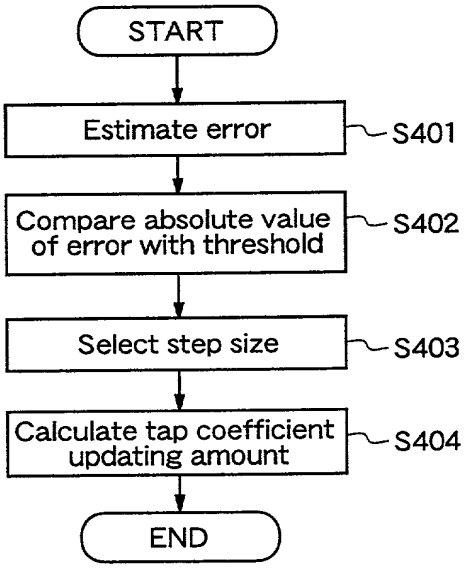

START
Estimate error
S401
Compare absolute value of error with threshold
S402
Select step size
S403
Calculate tap coefficient updating amount
S404
END

Fig.27

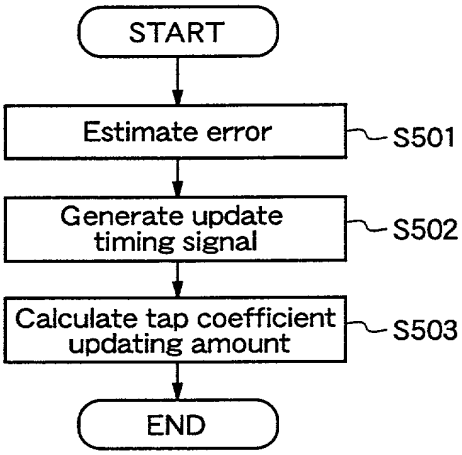

START
Estimate error
S501
Generate update timing signal
S502
Calculate tap coefficient updating amount
S503
END

Fig.28

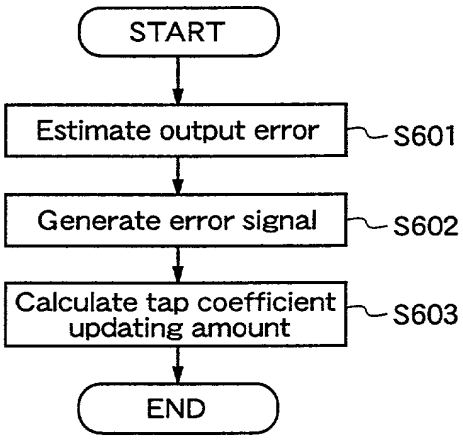
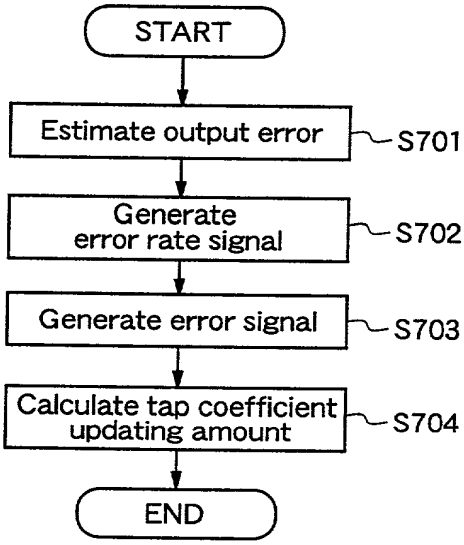

START
Estimate output error
S601
Generate error signal
S602
Calculate tap coefficient updating amount
S603
END

Fig.29


START
Estimate output error
S701
Generate error rate signal
S702
Generate error signal
S703
Calculate tap coefficient updating amount
S704
END

Rev. 11-3/98 Effective March 1998

DECLARATION AND POWER OF ATTORNEY FOR U.S. PATENT APPLICATION

(X) Original () Supplemental () Substitute () PCT () DESIGN

As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that I verily believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Title: WAVEFORM EQUALIZATION CONTROLLER AND WAVEFORM EQUALIZATION CONTROL METHOD

of which is described and claimed in:
() the attached specification, or
(X) the specification in application Serial No. _____, filed October 30, 2000, and with amendments through (if applicable), or
() the specification in International Application No. , filed , and as amended on (if applicable).

I hereby state that I have reviewed and understand the content of the above-identified specification, including the claims, as amended by any amendment(s) referred to above.

I acknowledge my duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim priority benefits under Title 35, United States Code, §119 (and §172 if this application is for a Design) of any application(s) for patent or inventor's certificate listed below and have also identified below any application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

COUNTRY	APPLICATION NO.	DATE OF FILING	PRIORITY CLAIMED
Japan	11-309872	October 29, 1999	Yes

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose information material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

APPLICATION SERIAL NO.	U.S. FILING DATE	STATUS: PATENTED, PENDING, ABANDONED

And I hereby appoint Michael R. Davis, Reg. No. 25,134; Matthew M. Jacob, Reg. No. 25,154; Jeffrey Nolton, Reg. No. 25,408; Warren M. Cheek, Jr., Reg. No. 33,367; Nils Pedersen, Reg. No. 33,145; and Charles R. Watts, Reg. No. 33,142, who together constitute the firm of WENDEROTH, LIND & PONACK, L.L.P., jointly and severally, attorneys to prosecute this application and to transact all business in the U.S. Patent and Trademark Office connected therewith.

I hereby authorize the U.S. attorneys named herein to accept and follow instructions from HAYASE & CO. as to any action to be taken in the U.S. Patent and Trademark Office regarding this application without direct communication between the U.S. attorneys and myself. In the event of a change in the persons from whom instructions may be taken, the U.S. attorneys named herein will be so notified by me.

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0925-0826

I further declare that all statements made herein of my own knowledge are true, and that all statements on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

1st Inventor _____ Date _____
Naoya TOKUNAGA

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Kazuya UEDA

3rd Inventor _____ Date _____

4th Inventor _____ Date _____

5th Inventor _____ Date _____

6th Inventor _____ Date _____

The above application may be more particularly identified as follows:

U.S. Application Serial No. _____ Filing Date October 30, 2000

Applicant Reference Number P-23754-01 Atty Docket No. 2000-1507A

Title of Invention WAVEFORM EQUALIZATION CONTROLLER AND WAVEFORM EQUALIZATION CONTROL METHOD

09/698,204 10/30/2000